MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXXVIII. FEBRUARY 8, 1918. NO. 4

ANNUAL GENERAL MEETING.

Major P. A. MACMAHON, D.Sc., Sc.D., LL.D., F.R.S., PRESIDENT, in the Chair.

The Report of the Auditors of the Treasurer's accounts for the year 1917 was read, and is given on p. 236.

The following Motion, proposed by the Council, was put from the chair, and carried:—

"That the set of volumes of the Athenæum belonging to the Society be presented to the Library which is being formed for the University of Louvain in the John Rylands Library at Manchester."

The Annual Report of the Council was partly read.

The Address was delivered by the President, after which the Gold Medal was handed to the Secretary, for transmission to Mr. John Evershed, to whom it had been awarded for his investigations of Radial Motion in Sun-spots and other contributions to Astrophysics.

The President then presented the Hannah Jackson (*née* Gwilt) Gift to the Rev. T. E. R. Phillips, to whom it had been awarded for his observations of Planets, Double Stars, and Variable Stars.

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner, together with the President's Address and the Report of the Auditors.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 340.

The thanks of the Meeting were given to the retiring Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

William R. Cullington, Trinity House Navigation School, Hull;
The Rev. William Frederick Archdall Ellison, M.A., B.D., The Rectory, Fethard-on-Sea, Waterford, Ireland; and
Arthur Joseph Kelley, 16 York Road, Edgbaston, Birmingham,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Frederick Chamberlin, LL.B. (Harvard), F.R.Hist.Soc., F.R.G.S., M.R.I., 6 Beulah Hill, Upper Norwood, S.E. 19 (proposed by W. B. Gibbs);
Shankar Rao Ullal Savoor, Trinity College, Cambridge (proposed by A. S. Eddington); and
Dr. Evert Jan baron de Vos van Steenwijk, The Observatory, Leiden, Holland (proposed by W. de Sitter).

Report of the Council to the Ninety-eighth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society:—

	Patron	Honorary Members	Fellows		Associates	Total
			Compounders	Annual Subscribers		
1916 December 31	1	1	235	466	48	751
Since elected	...	...	...	+18	+4	...
Deceased	...	...	−9	− 6	−2	...
Resigned	...	...	...	− 5	...	...
Since compounded	...	...	...	...	...	...
Removed from list	...	...	...	−11	...	...
1917 December 31	1	1	226	462	50	740

(Seven Associates are also Fellows, and are therefore counted twice in the above table.)

Mr. Knobel's Account as Treasurer of the Royal

RECEIVED.

	£	s.	d.	£	s.	d.
Balances, 1916 December 31 :—						
At Bankers', as per Pass-book	298	12	6			
In hand of Assistant Secretary on Petty Cash Account	13	0	6			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	0	19	6			
				312	12	6
Received on account of Dividends :—						
£1,250 Metropolitan 3-per-cent. Stock ...	28	2	8			
£2,000 Swansea Corporation 3½-per-cent. Stock	52	10	0			
£3,500 East Indian Railway 3-per-cent. Debenture Stock	78	15	0			
£3,500 London and North-Western Railway 3-per-cent. Debenture Stock	78	15	0			
£4,000 Midland Railway 2½-per-cent. Debenture Stock	75	0	0			
£1,000 Lancashire and Yorkshire Railway 3-per-cent. Preference Stock	22	10	0			
£2,400 Gas Light and Coke Co. 3-per-cent. Debenture Stock	54	0	0			
£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock	45	0	0			
£1,000 War Loan 4½-per-cent. Stock	2	19	2			
£1,000 War Loan 5-per-cent. Stock, converted from 4½ per cent. Stock	50	18	9			
£500 War Loan 5 per cent. Stock	12	10	0			
				501	0	7
Received on account of Subscriptions :—						
Arrears	168	0	0			
Annual Contributions for 1917	684	12	0			
,, ,, in advance	6	6	0			
Admission Fees	33	12	0			
First Contributions	28	7	0			
				920	17	0
Sales of Publications :—						
At Society's Rooms	33	3	0			
At W. Wesley & Sons' £127 11 9						
Less 10 per cent. discount 12 15 0						
	114	16	9			
Herschel's Works: half share, received from Royal Society	3	17	6			
				151	17	3
Sales of Photographs				34	6	3
London Mathematical Society, for use of Rooms ...				30	0	0
Income Tax refunded by Commissioners of Inland Revenue				146	13	10
Waste Paper sold				3	15	6
Cheques outstanding				25	8	6
Debit Balance at Bankers', 1917 December 31, as per Pass-book				227	0	11
				£2,353	12	4

Examined and found correct.

(Signed) G. J. NEWBEGIN.
H. P. HOLLIS.
D. BAXANDALL.

1918 *January* 24.

Astronomical Society, from 1917 *January* 1 *to December* 31.

PAID.

	£ s. d.	£ s. d.
Assistant Secretary: Salary	250 0 0	
,, ,, Editing Society's Publications	50 0 0	
Clerk: Salary £100 0 0		
Less Army pay 39 8 6		
	60 11 6	
Assistant Clerk: Salary	54 12 0	
Porter and wife: Wages	99 17 6	
		515 1 0
House Duty	2 12 6	
Fire Insurance (2 years)	21 6 0	
Aircraft Insurance (2 years)	6 12 0	
Insurance of Stock at printers' (Fire and Aircraft)	2 12 0	
Servants' Insurance Stamps	1 6 6	
		34 9 0
Printing, etc.:—		
Monthly Notices	555 1 5	
Memoirs	260 2 10	
List of Fellows and Miscellaneous	58 16 4	
Photo-engraving	22 4 2	
		896 4 9
Reproduction of Photographs for sale		17 0 4
Turnor and Horrox Fund: Purchase of Books for Library		17 5 0
Expenses of Meetings	18 9 10	
Attendance to Lantern	3 10 0	
Time Signal: Rental of Wire	5 0 0	
		26 19 10
Subs. to Bureau Internat. pour Télégrammes Astron.	1 19 5	
Telephone Subscription	6 10 0	
Registration of Telegraphic Address	1 1 0	
Postage and Telegrams (including postage of Monthly Notices and Memoirs)	93 6 1	
Carriage of Parcels	0 3 8	
Stationery and Office expenses	12 17 11	
		115 18 1
House expenses; Allowance and sundry expenses	24 8 7	
Coal, Gas, and Electric Light	88 5 8	
Sundry fittings and repairs	1 7 7	
Sundries	4 16 2	
		118 18 0
Gold Medals		52 10 0
Subscription to Board of Scientific Societies ...		20 0 0
Expenses of Meetings of London Mathematical Society		15 8 11
Lee and Janson Fund Grants		12 0 0
Council Grant to Mr. Engelson		10 0 0
Purchase of £500 5-per-cent. War Loan Stock ...		475 0 0
Cheque-book and Bankers' charges on cheques ...		0 11 8
Cheque outstanding, 1917 January 1		3 0 0
Balances, 1917 December 31:—		
In hand of Assist. Sec. on Petty Cash Account	0 11 11	
,, ,, on Account of Turnor and Horrox Fund ...	8 14 6	
		9 6 5
Cheques outstanding, 1917 December 31		12 10 3
Interest on overdraft at Bankers'		1 9 1
		£2,353 12 4

Report of the Auditors.

We have examined the Treasurer's accounts of receipts and expenditure for the year 1917, and have found and certified the same to be correct. The Auditors specially note that the accounts for the year show a debit balance at the bankers' on 1917 December 31 of £227 0*s.* 11*d.*, which is due, as will be seen by the account, to the purchase of a sum of War Loan Stock, and to the expenditure incurred during the year in printing certain Memoirs of the Society.

The funded property of the Society has been increased by the purchase of £500 5-per-cent. War Loan Stock, and the £1000 4½-per-cent. War Loan Stock has been converted into 5-per-cent. War Loan Stock.

The books, instruments, and other effects of the Society have been examined, and appear to be in a satisfactory condition. The Auditors note that the stock of the Society's publications has been suitably packed and arranged.

A list has been laid on the table of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against the name of each. This list does not include the name of any such Fellow who is on Active Service, and who has availed himself of the privilege granted by the By-law special to the present War, passed on 1917 June 8.

(Signed) H. P. Hollis.
G. J. Newbegin.
D. Baxandall.

Gifts to the General Funds of the Society.

In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2,000 Consols.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2,000, free of legacy duty.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1917 Jan. 1. Balance of Fund	45	0	10	1917. Grants from Fund	12	0	0
Dividends, East Indian Railway	10	0	9	1917 Dec. 31. Balance of Fund	43	1	7
	£55	1	7		£55	1	7

The Turnor Fund and the Horrox Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrox: to this the Society added the sum of £55 15*s.*, and the whole now stands in £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

	£	*s.*	*d.*		£	*s.*	*d.*
1917 Jan. 1. Balance of Fund	5	19	2	1917. Purchase of Books	17	5	0
1917. Dividends, East Indian Railway ...	17	1	0	1917 Dec. 31. Balance of Fund	5	15	2
	£23	0	2		£23	0	2

The Hannah Jackson (née Gwilt) Fund: In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	*s.*	*d.*		£	*s.*	*d.*
1917 Jan. 1. Balance of Fund	44	8	5	1917 Dec. 31. Balance of Fund	53	14	5
1917. Dividends, East Indian Railway ...	9	6	0				
	£53	14	5		£53	14	5

Assets and Present Property of the Society, 1918 *January* 1.

	£ s. d.	£ s. d.
Debit Balance at Bankers', as per Pass-book, 1917 December 31		227 0 11
Cash in hand of Assistant Secretary on Petty Cash Account	0 11 11	
Cash in hand of Assistant Secretary on account of Turnor and Horrox Fund	8 14 6	
		9 6 5
Debit balance		217 14 6
Due on account of Subscriptions:—		
2 Contributions of 4 years' standing	16 16 0	
23 ,, 3 ,, ,, ...	144 18 0	
36 ,, 2 ,, ,, ...	151 4 0	
67 ,, 1 ,, ,, ...	140 14 0	
Other sums	10 19 0	
	464 11 0	
Less Contributions paid in advance	6 6 0	
		458 5 0
Due for Publications supplied from Society's Rooms	2 14 9	
Due from Wm. Wesley & Son for sales of Publications during the last quarter of 1917	18 15 7	
		21 10 4

£1,250 Metropolitan 3-per-cent. Stock.

£2,000 Swansea Corporation 3½-per-cent. Stock.

£3,500 East Indian Railway 3-per-cent. Debenture Stock.

£3,500 London and North-Western Railway 3-per-cent. Debenture Stock.

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£1,000 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

£2,400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock.

£1,500 War Loan 5-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, etc.

Stock of Publications and Photographs.

Four Gold Medals.

Celestial Photographs.

The following has been added to the list of Celestial Photographs reproduced by the Society for sale to the Fellows :—

R.A.S. Ref. No.

276. Jupiter 1916 October 23, J. H. Reynolds.

A catalogue of photographs, Nos. 1 to 234, was published in the Annual Report for 1912 (*M.N.*, 72, 225). Supplementary lists were given in the Reports for 1915, 1916, and 1917.

The Award of the Gold Medal.

The Council have awarded the Society's Gold Medal to Mr. John Evershed for his investigations of Radial Motion in Sunspots and other contributions to Astrophysics. The President will lay before the Society the grounds upon which the award has been founded.

The Hannah Jackson (née Gwilt) Gift.

The Council have awarded the Hannah Jackson (née Gwilt) Gift to the Rev. T. E. R. Phillips for his observations of Planets, Double Stars, and Variable Stars.

Publications of the Society.

During the past year vol. lxxvii. of the *Monthly Notices* has been published.

The following volumes of the *Memoirs* have also been published :—

Vol. lxi., R. Jonckheere, "Catalogue and Measures of Double Stars."

Vol. lxii., part 1, J. H Jeans, "The Motion of Tidally-distorted Masses ; with special reference to Theories of Cosmogony."

Vol. lxii., part 2, L. Becker, "On the positions of some Pole Stars, and a new determination of the Constant of Aberration."

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Rev. Frank Besant.
William Henry Besant.
Arthur Matthew Weld Downing.
Rev. Paul Wynyard Fairclough.
Gerard Brown Finch.*
Alexander Foote.
Joseph Alfred Hardcastle.
William Ernest Hartley.
Maurice Egerton Leigh-Hunt.
Burdett Mason.
John Earle Maxwell.
Richard Frind Roberts.
Rev. Philip R. Sleeman.
William Harold Tingey.
William Henry Walmsley.†

Associates :—Friedrich Robert Helmert.
Edmund Weiss.

An obituary is also given of John Tebbutt, who died in December 1916.

Rev. Frank Besant was born in 1841, and entered at Emmanuel College, Cambridge, in 1860, graduating as 28th Wrangler in 1863. He was brother of Sir Walter Besant the author, and also of Dr. William Henry Besant, whose obituary follows. It is noteworthy that all three brothers were educated at Stockwell Grammar School, and all were Wranglers. He was ordained at Winchester in 1866, and held an assistant mastership in mathematics at Cheltenham College for six years, 1865–1871 ; in 1871 he was offered, and accepted, the living of Sibsey, Lincolnshire, four miles from Boston, which is in the patronage of the Lord Chancellor. He remained here for the rest of his life, a period of forty-six years, dying on 1917 April 21.

His wife was Mrs. Annie Besant, lecturer and writer on socialism and theosophy.

He was elected a Fellow of the Society on 1866 November 9, and was also a Fellow of the Royal Geographical Society.

* Deceased 1913, death not reported till 1917.
† Deceased 1916, death not reported till 1917.

William Henry Besant was born at Portsea on 1828 November 1, being the son of Mr. William Besant, merchant, of Portsmouth. He was educated at St. Paul's School, Southsea. At the age of 16 he competed for a classical scholarship at Corpus Christi College, Oxford, and was second on the list. Two years later he entered St. John's College, Cambridge, graduating as Senior Wrangler in 1850, and being first Smith's Prizeman. He was elected a Fellow in 1853; in 1859 he vacated his Fellowship, not being in Holy Orders, but resumed it in 1899. He was a mathematical lecturer at St. John's College from 1853 to 1889, and the author of treatises on Conic Sections, Dynamics, Hydromechanics, an interesting tract on "The Geometry of Roulettes and Glissettes" (1869), and various mathematical papers. He gained a great reputation as a mathematical coach, and had many distinguished pupils, including Professor W. Burnside, Professor G. B. Mathews, and Professor A. W. Flux. He also took a prominent part in the University, being Esquire Bedell for a time, and Examiner for the Mathematical Tripos in 1856, 57, 85. He also served on many of the Syndicates. He was Examiner in the University of London 1859–64.

He was elected a Fellow of the Royal Society in 1871.

In company with the other famous mathematical coach, Dr. E. J. Routh, he received in 1883 the first Sc.D. given by the University of Cambridge.

The most striking characteristic to one who knew him in later years was his atmosphere of cheerful kindliness, and patience under considerable suffering. For many years before his death he could hardly walk upstairs owing to acute rheumatism, but he did not allow this to interfere with his gaiety of heart. He enjoyed renewing old acquaintances, and continued to retain an interest in the activities of younger men, on many occasions taking pleasure in signing their certificates as candidates for the Royal Society. Desiring to hint to a young examiner that the questions he had set were not altogether suitable, he chaffed him on the "coruscations" he had noticed in the papers. He would often recall his admiration for Maxwell, saying that he never had a conversation with him without gaining a new idea.

To such men as he Cambridge owes a great debt.

He married in 1861 Margaret Elizabeth, daughter of the late Rev. Robert Willis, Jacksonian Professor of Natural Philosophy at Cambridge from 1837 to 1875.

Mrs. Besant died in 1911, and Dr. Besant on 1917 June 2, at the age of 89. He leaves two sons and one daughter.

He was elected a Fellow of the Society on 1854 February 10, and was our oldest Fellow at the time of his death.

Arthur Matthew Weld Downing was born at Carlow on 1850 April 13. He was the younger son of Arthur Matthew Downing of Co. Carlow, and received his early education under Mr. Philip Jones at Nutgrove, then a well-known school near Rathfarnham,

Co. Dublin. From Nutgrove he passed to Trinity College, Dublin, where he had a distinguished career, specialising in mathematics, and obtaining the scholarship in science in 1871, in the winter of which year he graduated as B.A., taking his M.A. degree ten years later. In 1893 the University granted him the honorary degree of Doctor of Science.

In 1872 an open competition was held under the Civil Service Commission for the appointment of an assistant at the Royal Observatory, Greenwich, in which Downing was successful, entering on his official duties on 1873 January 17. The character of the position which he thus won was entirely congenial to him, his somewhat reserved nature and methodical habits finding satisfaction in the retired life and orderly routine of the Observatory. His mathematical tastes led him to find pleasure in computations, and during the greater part of his nineteen years at Greenwich the reductions of the Circle observations, and, later, those of the Altazimuth and Equatorial observations, were carried out by him or under his superintendence. For over ten years the care of the library and manuscripts was also in his hands, and for nearly the whole of his time at the Observatory he was one of the four regular observers with the Transit-Circle and Altazimuth.

Downing had not been long at Greenwich before he made himself known by the papers on the astronomy of precision which he communicated to this Society, the first of these being a short note on "A Determination of the Semi-diameter of Venus at the mean distance of the Sun from the Earth," appearing in the *Monthly Notices* for 1877 May. A series of more than thirty papers followed, dealing with the comparison of star places in different catalogues, their correction for systematic errors, the computation of proper motions, and other inquiries important in fundamental astronomy. These won him a reputation as an able and conscientious worker in this essential but less popular side of the science, and when, in 1891, Dr. J. Russell Hind, Superintendent of the *Nautical Almanac*, resigned his post, Downing was clearly marked out as his proper successor, and entered upon his new appointment on 1892 January 1.

Here began his real life-work, for which his natural bent, his education at Dublin, and his experience at Greenwich had admirably fitted him. The quiet, withdrawn, old-world corner of Gray's Inn, the responsible routine of the computations for the "Seaman's Bible," varying so little from one year to another, were exactly fitted to his temperament. Of undoubted ability, shrewd, determined, and far-seeing, and possessed of a great amount of energy, the *Nautical Almanac* was in safe keeping in his hands, and during the years he held the post his mental alertness suggested a number of alterations and improvements which he carried out most successfully. In particular he greatly increased the number of "Nautical Almanac Stars," earning thereby the gratitude alike of astronomers, seamen, and surveyors. Under his hand also additions were made to the section of planetary satellites, and

physical ephemerides of the planets were introduced. On the other hand, he witnessed the demise of "lunar distances," that hoary method that had well served its day and generation.

Methodical himself in all his work, punctilious and careful, cautious and straightforward in all official matters, he set the highest value on the work of his staff, and as a trained, practical observer knew how to insist on the need for extreme accuracy throughout the various calculations. To his knowledge of mathematics he added decided skill in computation, but although he was less liable than most men to make mistakes, he in no case allowed himself to dispense with the most scrupulous revision of any work that he had in hand. His extensive command of dates and figures did not, however, always save him from an occasional blunder, and it was a joke against him that on one occasion he dated a cheque two years ahead, the cheque coming back with a notification that it was post-dated. After all, it was a natural mistake for one to make whose main work was wholly devoted to events due to occur some years ahead.

In addition to his strictly official work, the queries that were showered upon him were many and varied, relating to chronology, the calendar, eclipses, astronomical constants, the construction of the *Nautical Almanac*, and kindred matters. One inquirer perhaps wanted to know the exact time of some full moon of a century ago; another, its age on the night of the Gunpowder Plot. Or such inquiries might be made of him as, "What was the time of high water at Dover when Julius Cæsar landed in August 55 B.C.?" Every inquiry of a sensible character received prompt attention, and even faddists and cranks were kindly dealt with when their peculiarities were confined within certain prescribed limits.

An extensive piece of work which occupied seven years of his official life was his revision of Taylor's *General Catalogue of* 11,000 *Stars for the Equinox*, 1835·0, *from Observations made at Madras Observatory*, 1831 *to* 1842. This work was a natural sequel to the numerous and important contributions he had made in previous years to this branch of sidereal astronomy. In his preface he says "That his (Taylor's) work may now be rendered more useful to astronomy is the reward for which I hope in the publication of this revised edition," and that aim and hope illustrate the keynote of his character. He found the question of the expected reappearance of the Leonids an interesting and profitable study for several years, during which he collaborated with the late Dr. Johnstone Stoney in an attempt to construct an ephemeris of the densest portion of the swarm. The calculations appertaining to this were made at H.M. *Nautical Almanac* Office under his superintendence, and went to show that the failure of the shower to reappear at the end of last century was probably due to the perturbations of the meteors by the action of Jupiter, Saturn, and Uranus, while the meteors were travelling at a great distance from the Sun. The main body of the swarm was thus

made to pass at a distance of nearly $1\frac{3}{4}$ millions of miles from the Earth's orbit.

Downing's term of office at Gray's Inn was marked by special efforts at co-operation between similar departments in other countries with the view of avoiding duplication of work, and led to the holding in Paris, in 1896 May, of an International Conference on Fundamental Stars, and the results of the Conference, the inauguration of which was due to him, were far-reaching.

In later years illness troubled Dr. Downing considerably and appeared to intensify his natural reserve. He retired from the *Nautical Almanac* in 1910 on completing the sixtieth year of his age. It is the testimony of a member of his staff who was with him throughout the years of his Superintendency, that "he was at all times fair, courteous, and considerate; he always consulted the interests of his staff, and was in every worthy movement a sympathetic helper."

His work at Greenwich Observatory and the *Nautical Almanac* represented his professional work in astronomy. But his interests were not limited to this, and he took a keen interest in what may be called amateur astronomy. Thus he had an important part in the founding of the British Astronomical Association, an Association especially intended for the help and organisation of amateur observers. He became its second President, 1892–1894, and for many years was a Member of its Council. He was the Secretary and organiser of its first Eclipse Expedition—viz. that to Vadsö—to observe the total eclipse of 1896 August 9, and the failure of the expedition from an astronomical point of view, owing to cloudy weather, was a great disappointment to him; its social success and the strength which it gave to the young Association were some compensation for his trouble. It should be noted, as showing his interest in eclipse problems, that during his term of office at Gray's Inn he was wont to issue circulars for the convenience of eclipse observers, giving local particulars of the times of occurrence and other helpful data in the case of notable eclipses.

He communicated in all seventy-five notes and papers to the *Monthly Notices*. He served nineteen years on the Council, during three of which he was Secretary and two Vice-President.

He was elected a Fellow of the Royal Society in 1896.

Reviewing Dr. Downing's career as a whole, it might be summed up by saying that the talents he displayed were sober and solid rather than brilliant, but the useful work which he accomplished entitles him to an honourable place among professional astronomers.

During his last years he suffered much at times from a painful affection of the heart, and the end came very suddenly on 1917 December 8. He leaves a widow and one daughter.

He was elected a Fellow of the Society on 1875 March 12.

W. F. D. and E. W. M.

Paul Wynyard Fairclough was born in South Australia in 1852. During the early sixties he went with his parents to reside in New Zealand at the time of the gold rush there. Educated for the purpose in Sydney, he entered the ministry of the Methodist Church in 1872, and served in that capacity in New Zealand with conspicuous success for forty-three years, occupying various posts of honour therein. He was eventually elected President of the Wesleyan Conference in 1897. These positions were conceded to him not because he sought them, but because of his personal gifts and fitness. For several years he held the office of editor of the denominational paper. He was a man of distinct individuality. In all departments of intellectual activity he manifested a keen interest. He excelled on the platform as well as in the pulpit. His oratory was clear, thoughtful, and convincing. On Imperial questions Mr Fairclough was ever in great demand, and responded with masterly eloquence. Astronomical circles were always enriched by his presence and activities, and he was ever ready to serve them with well-prepared and up-to-date contributions. He was one of the Vice-Presidents of the Dunedin Astronomical Society, which owes much to his administrative wisdom and guidance. Several of his papers on scientific — mainly astronomical—subjects were read before the philosophical societies of New Zealand, and some of these appear in the *Transactions of the New Zealand Institute*. Mr Fairclough was unexcelled as a writer of monthly astronomical notes, and he rendered a signal service to our science in that way alone. His love for astronomy was a genuine passion. As a writer and speaker Mr Fairclough's style was incisive, clear, penetrating, epigrammatic, and was often marked by rich humour. His very appearance roused expectations, and none were disappointed in him, though he was often reticent and reluctant to reveal himself. His stalwart manliness, his kindly and practical interest in those whom he believed in and could help, together with his scorn of littleness, drew to him all who were privileged to know him. He quietly passed away on Wednesday, April 18th, shortly after an operation upon which heart failure supervened, leaving his widow (formerly Miss Aiken, of Canterbury), one daughter, and three sons to mourn their loss.

He was elected a Fellow of the Society on 1900 January 12.

[The Council are indebted for the above notice to Rev. B. Dudley.]

Alexander Foote was born at Rosehill, Forfarshire, in 1850 August, and died at Newland House, Bath, on 1917 June 6. After leaving Trinity College, Oxford, where he took honours in Moderations, he entered for the Bar, but his great love for music led him to abandon the law as a profession, and he spent some time in Italy in the study of music. Returning to Scotland in 1873, he joined the Royal Company of Archers, the King's Bodyguard for Scotland. A serious illness having left him in poor health, he was unable to take any very active part in public affairs, and

during many years he spent most of his time upon music, including the composition of songs, pianoforte pieces, and anthems. He was also very fond of poetry, and took a keen interest in theological questions.

He had always been interested in astronomy, and about the year 1900, while residing at Earl's Court, he procured a portable telescope, and took up the serious study of the subject, with some assistance from Professor Fowler and Mr. W. Shackleton. He was especially attracted by celestial spectra, for which he used a Zöllner star spectroscope and an objective prism. In *Knowledge* for 1903 he gave a very useful description of the spectra of several of the brighter stars as seen with his small outfit. He also made spectroscopic observations of the Sun, making use of a small polar heliostat, which he afterwards presented to the Society.

After settling at Lansdown, Bath, in 1906, he built an observatory, equipped with a $3\frac{1}{2}$-inch Cooke equatorial. He was also provided with a 5-inch telescope having an altazimuth mounting, a 4-inch comet-seeker, and some smaller instruments. So far as his health permitted he continued to make observations, and derived enormous pleasure from what he was able to do. In the hope of encouraging the study of astronomy Mrs. Foote has generously lent the observatory and two of the smaller telescopes for the use of the pupils of the Royal School for Officers' Daughters.

In 1880 Mr. Foote married Alice Mary Robertson, who died in 1889, leaving him with two sons. In 1892 he married Janet Margaret Wilkinson, and had one daughter. His eldest son is engaged on Government work in Mexico, and the second son is in command of a destroyer in the Royal Navy.

He was elected a Fellow of the Society on 1900 May 11.

Joseph Alfred Hardcastle was the eldest son of Maria Sophia, the third daughter of Sir John F. W. Herschel, who married Mr. Henry Hardcastle, son of Mr. Joseph Alfred Hardcastle, M.P., in 1865. He was born on 1868 August 27, and was educated at Harrow, where he was head of the Modern side and won the Neeld Gold Medal for Mathematics in 1886. He further distinguished himself as a school-boy by passing the examination for the Indian Civil Service, but of this success he did not take advantage. He went up to Trinity College, Cambridge, in the same year (1887), but owing to family reasons left the University in 1888, and, proposing to follow a business career, learnt the art of brewing. In 1890, unfortunately, he was attacked by the complaint from which he suffered for the remainder of his life, and had to spend many winters abroad, in Egypt (where he worked in a bank at Alexandria), Switzerland, and Italy. In 1897 he returned to Cambridge with the hope of taking a degree, but ill-health compelled him again to leave the University without this being accomplished. In 1899 he married Theresa Selina Clive, youngest daughter of Sir Edward Clive Bayley, K.C.S.I.,

C.I.E., when he gave up business, and made astronomical lecturing and teaching his profession, the science always having had an attraction for him. He excelled in this branch of work, and made effective use of models and ingenious mechanical devices, which he planned and used with much skill, of which his lecture on Gyroscopic motion supplied a typical example. This lecturing and teaching work was very congenial to him, because it brought him into touch with so many human beings, and because, as he said, he was able to bring into their lives a new and absorbing interest. He always urged his pupils to make simple astronomical observations, and arranged schemes for this purpose with success. In 1901 he was placed on the staff of the Oxford University Extension Delegacy, and was a member of the Cambridge Extension Syndicate, being an "A" lecturer in each case. He also lectured for other organisations, and in this connection it may be mentioned that he was a candidate for the Gresham Lectureship in 1909, when the late Mr. Saunder was appointed, and it was felt by one who heard the competitive lectures which are given on such occasions, that the electors must have had some difficulty in making their decision.

Some years after his marriage Hardcastle spent some time abroad, and worked for a few months at the University Observatory, Oxford. In 1903 he went to live at Crowthorne, Berkshire, near Wellington College, in order to help Mr. Saunder in the lunar work in which the latter was engaged. Mr. Saunder, being aware of the inadequacy both in number and accuracy of the measured positions on which the standard maps of the moon are based, obtained from M. Loewy four negatives of the Moon taken under different librations with the equatorial coudé of the Paris Observatory, and arranged a scheme for the measurement of these which would result finally in a better knowledge of positions of the features of the lunar surface. The measures of these negatives, more than 20,000 pointings in all, were made by Mr. Hardcastle at his house in Crowthorne with a micrometer lent from the Oxford University Observatory, and in the published account of this work (*Mem. R.A.S.*, 47, part 1), Mr. Saunder says that it is to his care and accuracy that the value of the whole is due. In 1902 Hardcastle joined the British Astronomical Association, and was elected Secretary in 1904 October. He held this position for six years, and his colleagues on the Council know with what energy he performed the duties of the office, not only in the part he took in the meetings, where he often contributed to the programme and discussion, but also in the internal organisation and management of the Association. His papers in the *Journal* of the Association are numerous, and all give evidence of his originality of thought and ingenuity. After 1910 his health scarcely permitted him to take any active part in the science. He gave up the Secretaryship of the Association, and refused the position of President, and though he was chosen to be a Vice-President, his attendances were few. His lecturing and teaching were almost given up, as travelling was difficult for him; but during these later years of his

life he accomplished the valuable work to be found in the *Monthly Notices* for 1914 June, which is a classification of the nebulæ shown on the series of 206 plates covering the whole sky, taken by Mr. Franklin Adams, and placed at his disposal by Sir Frank Dyson. He served on the Council of our Society from 1907 February to 1910 February, and again from 1912 to 1914. Very naturally he acted on the Committee of publication of Sir William Herschel's papers, and gave much efficient help. On the retirement of Dr. Dreyer from the Directorship of the Observatory at Armagh, Hardcastle, whose health had apparently improved, was chosen by Archbishop Crozier, Primate of Ireland, to succeed him, and was to have taken up the appointment in June last. The selection was an ideal one, but its actual realisation was tragic. Mr. and Mrs. Hardcastle with their family were on the point of starting for their new home when Hardcastle's complaint renewed itself, and he was not able to make the journey, but was obliged to go to his father's house at Oxted, where he died on November 10 last at the early age of forty-nine, and was buried at Oxted on November 13.

Alfred Hardcastle was a deeply religious man, and took an active part in the parochial and church life of the parish of Crowthorne. He was a delightful companion, and had a charm of manner that endeared him to all who met him. The high regard and esteem in which he was held by his pupils is touchingly expressed in an appreciative contribution to the *Journal of the British Astronomical Association* for 1917 December, written by two of them, Miss Blagg and Miss Cook, now both Fellows of this Society. He leaves a widow, a son, and one daughter.

He was elected a Fellow of the Society on 1902 January 10.

H. P. H.

William Ernest Hartley was born at Walsall, Staffordshire, in 1877, and was educated at King Edward's High School, Birmingham; and at Trinity College, Cambridge, of which foundation he was a Scholar. In 1899 he graduated as sixth Wrangler in the Mathematical Tripos. For several years subsequently he held the post of Demonstrator in Physics at the University of Aberdeen. In 1903 he was appointed Second Assistant at the Cambridge Observatory, and when Mr. Hinks left to take a secretaryship in the Royal Geographical Society, Mr. Hartley succeeded him as Chief Assistant, where he was placed in charge of the meridian-circle and employed on the re-observation of the faint supernumerary stars of the Cambridge Zone Catalogue, as well as in the preparation for press of the detailed observations of this Zone—a work which he completed a few months before his death. These tasks left him little time for original work. But he took a large share in a determination of the systematic motions of stars from the radial velocities, which indicated a close quantitative agreement between the radial velocities and proper motions in regard to the phenomena of star-streaming. He was also very successful as a teacher of practical

astronomy to university students at the Observatory; and he gave considerable assistance to the late Director, Sir Robert Ball, in connection with his professional publications. Mr. Hartley's great gifts of lucid explanation, combined with his skill in the manipulation of astronomical instruments, made him eminently popular and successful in the weekly Saturday night demonstrations with the Northumberland equatorial. Towards the close of 1915 he decided to put his services at the disposal of his country during the war, the tragic possibilities of which for himself he and his wife fully and fearlessly faced. On 1916 January 4 he accepted a post as naval instructor for the duration of the war, and went to reside at the Royal Naval College, Greenwich. During this time he paid regular week-end visits to Cambridge and helped to carry on the work in the Observatory. In May he was appointed to H.M.S. *Africa*; and in December of that year was transferred to the ill-fated *Vanguard*, in the disaster to which he met his death during the night of 1917 July 9. Before joining the Navy he had been qualifying himself for military service in the M.A. Training Corps at Cambridge. As a naval instructor he naturally found full scope for his special talents. In a letter of condolence written to the widow, Admiral Sturdee spoke in the highest terms of his excellence as an instructor, and of the conscientious thoroughness of his work in general.

In 1909 Mr. Hartley married Norah Winifred, fifth daughter of Mr. James A. Aldis, of Miasmere, Suffolk, formerly headmaster of Queen Mary's School, Walsall. She survives him, with two daughters. He will long be remembered by his friends and his professional colleagues, both in the Observatory and in the Navy, as a keen and devoted worker, a genial comrade, and a man of singularly unselfish kindliness. That a career of such promise should have been so abruptly broken off is one of the tragedies of war.

He was elected a Fellow on 1914 January 9.

[For the above notice the Council are indebted to Mr. H. L. Aldis.]

Maurice Egerton Leigh-Hunt was born on 1871 June 1, matriculated from St. Paul's school, and shortly afterwards went to Mexico on a mining mission. Upon returning to England he became ultimately a member of the London Stock Exchange and a partner in a well-known firm of brokers. A keen observer, he built a movable shed for his principal telescope, and thought no outlay of time or money too great if it facilitated the astronomical studies to which he was devoted.

He died suddenly in his office in the City on 1917 September 15. He had been suffering for some time from a weak heart, but it was not regarded with any seriousness, and his sudden death came as a great shock to the wide circle of friends by whom he was warmly esteemed.

He married Georgina Millicent, daughter of the late Mr. J.

Hanbury-Jepson, of Folkestone, who survives him, and he leaves three children, two girls and a little boy.

He was elected a Fellow of the Society on 1913 April 11.

Burdett Mason was born in 1853 in New Haven, Connecticut. He began life as a musician and composer, also giving much time to painting. Subsequently he became interested in astronomy, and built an observatory at his residence, Château Larondouette, near Bayonne, the equipment including a good 6-inch telescope, which after his death was purchased by the Institut de France for the Abbadia Observatory, Hendaye.

The year before the war he accepted the position of American Consular Agent for the Basses Pyrénées. He only contemplated a temporary holding of this office, but on the outbreak of war he resolved to continue it for patriotic motives. However, the work proved so arduous and exacting that his health, never robust, broke down under the strain, and he died on 1917 June 17. The funeral oration was pronounced by Vicomte de Wildik, Consul-General for Portugal. The following extract from it shows the high esteem in which Mr. Burdett Mason was held :—

"The grief of our consular body is very sincere; it is due to the high qualities which he showed in his work. His zeal and devotion to the interests which his country entrusted to his care; his kindness and extreme courtesy to all who had business at his consulate; his intimate acquaintance with the spirit and the objects of the consular institution; his tact and prudence, so necessary and valuable in his relations with the local authorities; his desire to help his fellow-consuls, and the liberality with which he responded to their charitable appeals for their respective countries—all these qualities concurred to render him an accomplished consul."

Mr. Burdett Mason married in 1884. His widow survives him, but his only child died young.

He was elected a Fellow of the Society on 1907 December 13.

John Earle Maxwell was born on 1892 June 24, and was the elder son of Mr. John A. Maxwell, solicitor, of 52 Bishopsgate and 84 Dartmouth Road, Brondesbury. He was educated at Haileybury, and on leaving school in 1911 began to study Law. However, after working at the latter for about two years he eventually decided to take up Medicine, and for this purpose entered Guy's Hospital in 1913 January. The outbreak of war found him still at a somewhat early stage in his medical course, and it was at first a little difficult for him to decide as to how he might best serve his country. On the one hand was the urgent call for fighting men, and on the other an alarming shortage of medical men, threatening to become daily more acute. For a time he continued his work at Guy's, hoping that he would soon be in a position to use his hospital training in the Public Service. In the end, however, he decided to serve in a combatant capacity,

and, in 1916 January, was given a commission in the R.N.V.R., being attached to the R.N.A.S. as an observer. After a few months' service in England he was ordered to the Eastern Mediterranean in the winter of 1916. On 1917 March 30 he set out with a pilot on a reconnaissance over enemy territory, but failed to return. He was at first reported missing, but several weeks later the news was received that the machine had been shot down and both pilot and observer killed.

Lieutenant Maxwell was an enthusiastic amateur astronomer. In 1908, while still at Haileybury, he began to make observations with a three-inch refractor, and also with a six-inch belonging to the school. He was particularly interested in the controversy centring round the Martian canals, and lectured more than once on this subject, his first lecture having been given before he left Haileybury. He was a clear thinker and a logical reasoner, and his opinions on the Martian question are well summarised in an article and several letters contributed by him to *Knowledge* in 1914.

He was an able observer, though his own equipment was not sufficient to enable him to do as much work as he would have wished. However, he did a good deal of work on the planets with the 10-inch refractor at Mr. Worthington's observatory. He was a member of the British Astronomical Association and of the Hampstead Scientific Society, and took an active part in the discussions at their meetings.

He was elected a Fellow of the Society on 1915 January 8.

[For the above notice the Council are indebted to his friend Mr. W. H. Steavenson.]

Richard Frind Roberts was born in London in 1849, and educated at Edmonton Grammar School. His father studied navigation with a view to obtaining a commission in the East India Co. He did not, however, complete his course, but the interest in astronomy which grew out of these studies remained, and was handed down to his son.

Richard Roberts' work in connection with astronomy was limited to the short hours of leisure which he could spare from his profession as a Chartered Accountant. His instruments were small, and perhaps the chief interest that his work affords lies in the fact that he succeeded in observing, with small portable instruments, objects that are often regarded as visible only through larger and more costly apparatus. Thus, for instance, with a 3·7-inch refractor, mounted on an ordinary altazimuth stand, and provided with a small spectroscope which Mr. J. Evershed kindly designed specially for him, he made regular observations of the Solar prominences.

In his later years he found it difficult to continue outdoor observations, so turned attention to other pursuits, including optical projection, spectroscopic analysis, pneumatics and horology. He installed a small wireless station at his house at Warlingham,

mainly with a view to receiving the time-signals from Paris and Norddeich.

When war broke out and the wireless was dismantled and interned, he applied himself to the sextant, and, with the aid of a ship's chronometer, succeeded in taking surprisingly accurate observations, finding no difficulty in determining the difference in latitude between two points within a garden of less than an acre in extent.

In 1900 he went to Algiers to view the Total Solar Eclipse, and in 1905 to Majorca for the same purpose. His observations of the times of contact and of the appearance of the shadow-bands in the 1900 eclipse are contained in the eclipse volume published by the British Astronomical Association. During last year, owing to depletion of staff at his office, he was assisted by his only daughter, and they were both killed instantaneously in the destruction of the building during the air raid of June 13.

He was elected a Fellow of the Society on 1906 January 12. He was a regular attendant at the meetings, but did not contribute any papers.

John Tebbutt was one of those enthusiastic non-professional astronomers who, with instrumental appliances of the humblest order and no outside help, make an indelible mark on our records. He fortunately wrote an autobiographical account * of his work ten years ago, which is in our library and was widely distributed, but many of the details are so full of interest as to be well worth repetition here.

He was born at Windsor, N.S.W., on 1834 May 25, and spent a long and peaceful life of nearly eighty-three years in that city or in the outskirts till his death in 1916 November. His grandfather, John Tebbutt, a Middlesex man, married Ann Halfpenny in 1788, and emigrated to New South Wales with his wife and three children in 1801. A great flood in 1809 brought hardship and losses on these early settlers: the two sons, Thomas and John, "landed from a small boat on the hill near the middle of the Peninsula Estate, and almost exactly on the spot now occupied by the observatories. . . . A heavy thunderstorm came on at the time, and they dragged the boat ashore, turned it over, and sheltered themselves under it from the storm." But gradually a business was built up, apparently with such success that there are practically no further references to financial troubles in the autobiography. But we may gather from the modesty of the astronomical equipment in the earlier years that resources were not too plentiful.

Mr. Tebbutt records his early educational facilities, which were of the usual classical order, with gratitude; but his own love of mechanism seems to have guided him to study first steam-engines,

* *Astronomical Memoirs, by John Tebbutt; being a Popular and Complete Account of the Astronomical Work done by him at the Peninsula, Windsor, N.S.W., from the year 1853 to the close of 1907.* Sydney: F. W. White, 1908.

then clocks, and ultimately the heavens. "It dawned on me that the universe was really mechanism of the highest order, and being, as I have already said, mechanically inclined, I began to turn my attention to celestial mechanism." Thus is the keynote of his long working life struck: celestial physics interested him but little —to use a telescope for looking at spots on the Sun he regarded (in the presence of several witnesses) as "amateurish"; his own instruments were used chiefly to discover and observe comets, and his leisure hours in checking numerically the marvellous accuracy with which they obey mechanical laws. Simon Newcomb has left on record the deep impression made upon himself when he first conceived of the universe as a piece of beautiful mechanism of which future configurations could be predicted from certain data: and there is no question but that so magnificent an idea is in itself sufficient motive for a devoted working life.

In 1853, at the age of nineteen, Mr. Tebbutt purchased a sextant and a copy of Norie's *Epitome of Navigation*. He had also the use of a "grandfather" clock, an "ordinary marine" telescope, and a celestial atlas; and with this equipment he set out to explore the heavens. He verified the Sun's rotation by making sketches of the spots (for this mechanical purpose they were apparently noteworthy), observed the comet of 1853 by aligning it with various stars, and calculated the solar eclipse of 1857, which, however, was unfortunately hidden by clouds. He also calculated the orbit of the 1853 comet from his own star alignments and those of 1858 (Donati) and 1860 III from sextant observations made by himself. The interest aroused by this work led him to search for comets, with immediate and startling success; for on May 13 he found the great comet of 1861, one of the largest in history. The discovery was by no means easy, however. At first the comet was faint and almost motionless, so that it might easily have been a nebula for all the information available. To bring a bright star near it with the sextant extinguished its faint light unless a coloured glass was used: Mr. Tebbutt was driven to compare the suspicious object with the star Lacaille 1316, and then to find the distances of the latter from well-known stars with his sextant. On May 16 the object had not sensibly moved, and he "had almost given up hope of its being a comet": then cloudy weather followed: on May 21 he got a glimpse or two through breaks, and began to hope again, and on May 22 he was sure of a change. He wrote off to the Government Astronomer (Rev. W. Scott), and on May 25 sent a letter to the *Sydney Morning Herald*. Continuing his observations and calculations assiduously he announced in the same paper, under date June 13, that the Earth would be "at no great distance from the extremity of the tail" on June 29: a prediction verified *ex post facto* in the northern hemisphere without any suspicion that it had been made by a young and unknown astronomer on the other side of the globe, cable news not being then available.

In 1861 November Mr. Tebbutt purchased a $3\frac{1}{4}$-inch telescope (by Jones of Liverpool), with which he observed Encke's Comet in

1862, and Swift's periodical comet (1862 III), recalling proudly that his observations of the latter were used in the definitive determination of the orbit by Hayn, and that "the Windsor telescope was the smallest employed at the twenty-seven stations from which the comet was observed." Moreover, these same observations led to his discovering one of those rare objects a "new star," though he did not realise it at the time, and his discovery has not yet been given a place in the lists of such objects (*e.g.* Harvard Circular No. 4). There seems, however, to be no room for doubt on the matter. We have already seen how the modesty of his apparatus led him to determine cometary places by stepping from star to star. In observing Swift's Comet on October 4 he stepped in this way from the comet to two stars (Brisbane 5754 and 5799), from them by ring micrometer observations to "a conspicuous star of the 5th magnitude," and on October 9 he connected this latter by sextant observations with θ Scorpii, Altair, Antares, and ϵ Sagittarii, finding its mean place for 1862·0 to be $\alpha = 17^h\ 29^m\ 2^s{\cdot}51$ $\delta = -45^\circ\ 23'\ 33''{\cdot}8$. He could not find this star in any catalogues at his command at the time, but this did not surprise him very much. In recurring to the place in 1877, however, he was surprised to find that the only object near the deduced position was a faint telescopic one. The C.P.D. gives no star in the place. It may confidently be said that Mr. Tebbutt was too good an observer to have made any mistake. He described his discovery fully in a paper to the Royal Society of New South Wales in 1877, but it has not been generally recognised. It is remarkable, firstly, as being a consequence of the restricted nature of his resources; for with better equipment he might never have been driven to make use of this intermediary; and secondly, for the fact that this new star should, as it were, obtrude itself on the attention for a useful purpose, as in the case of Nova Geminorum in 1903, which offered itself to Mr Bellamy at Oxford as a guiding star. This particular achievement, however, was not recognised at the time; but the cometary discoveries and work generally were so well appreciated, that in 1862, on the retirement of the Rev. W. Scott, Mr. Tebbutt was offered the post of Government Astronomer. He declined it "for reasons assigned at the time," and continued to work with quite small optical means for another twenty years.

In 1863 he built a small observatory with his own hands, being "carpenter, bricklayer, and slater," in which he installed a 2-inch transit (by Tornaghi of Sydney), a box chronometer, and the $3\frac{1}{4}$-inch above mentioned. He used the transit both in the meridian for time and in the prime vertical for latitude. In 1872 he added a $4\frac{1}{2}$-inch equatorial, which he bought for £100.

It was not until 1886 that he obtained an instrument which many astronomers would regard as a minimum equipment—an 8-inch Grubb, for which he paid £400; but so great had been his assiduity, that he had by this time (1886) made over sixty communications to this Society and over seventy to the *Astronomische Nachrichten*, besides minor notes. The list of his papers ultimately exceeded

300. They included observations of the Transit of Venus in 1874 (that in 1882 was cloudy), of various eclipses of the Sun, Moon, and of Jupiter's satellites; of the longitude and latitude of his observatory; of places of various minor planets, and of Neptune, Uranus, Saturn, and Jupiter, by equatorial comparisons with stars, of occultations, of variable stars, in addition to the numerous cometary observations and calculations which formed the staple.

While subsequent years failed to provide discoveries like those of a large comet in 1861 and of a new star in 1862, they brought opportunities for thoroughly useful, if less sensational, work in plenty; but in view of the completeness of the autobiographical account already mentioned, it is perhaps scarcely necessary to give the details here.

In 1904 Mr. Tebbutt decided to retire from systematic astronomical work at the age of seventy, and a cordial message of appreciation was sent him on the occasion by the Royal Society of New South Wales. In 1905 this Society awarded him the Hannah Jackson (*née* Gwilt) Gift. There is no doubt that such recognitions were keenly enjoyed. The visit of a party of English astronomers (including the Astronomer Royal) in 1914, when the British Association met in Australia, was specially welcome. They found the observatory still in excellent working order, and were proudly shown the sextant and other early apparatus which had done such historic work. The journey from Sydney to Windsor was not a serious undertaking for a motor car, but with earlier facilities for transit must have been an effective barrier against frequent visits. Nevertheless Mr. Tebbutt accepted the first Presidency of the Sydney Branch of the British Astronomical Association in 1895, and honourably discharged the duties thus undertaken.

He was elected a Fellow of the Society 1873 January 10.

H. H. T.

William Harold Tingey was born in 1868 at Rochester, where his family had resided for many years, owning cement works, which have now been acquired by a company. He was educated at Brighton College and Trinity Hall, Cambridge, where he studied law, being subsequently called to the Bar; he did not, however, practise as a barrister.

He married about 1892 Miss M. Tovey, daughter of Colonel Tovey, R.E. She survives him with two sons, the elder of whom is a Captain in the R.E. and an expert in wireless telegraphy.

Besides his interest in astronomy, Mr. Tingey followed many other scientific pursuits, and was also well known as an amateur actor.

He died on 1917 August 3 in a nursing home as the result of an operation. He was sincerely respected, and his death is deplored by a large circle of friends.

He was elected a Fellow of the Society on 1899 February 10, and was also a Fellow of the Royal Meteorological Society.

William Henry Walmsley was born in 1860 December at Liverpool. After receiving his earlier education in that city he studied at University College, Gower Street, and under Professor Silvanus P. Thompson at the Finsbury Technical College. Several years later he read for the London B.Sc. in his spare time in the evenings after office work, and graduated with honours in 1891. After spending about two years as a computer at Greenwich Observatory he obtained by examination an assistantship in the *Nautical Almanac* Office in 1880. Here he became expert in the various stages and branches of prediction; as a linguist he supplied the office from time to time with translations of foreign communications and papers, missing neither point of scientific import nor touch of international courtesy. A trusty and trusted helper, and a colleague with whom it was invariably a pleasure to work, he delighted in placing his knowledge at the disposal of any and all who approached him. He took a pride in "England's home of interpolation" (as he once called the Office), and strove that it might, as far as his part was concerned, be first among its equals in work for international ephemerides. In spite of chronic ill-health he rarely showed outward sign of depression, and then only through some solicitude for work or workers; otherwise his cheerfulness was serene. He was an omnivorous reader, with a literary sympathy with Charles Lamb. With the exception of a passion for boating he was not keenly interested in athletics. Though his published contributions to astronomy fill many pages of many almanacs, his lot and choice lay largely with the "sundries" which look so little, and yet involved much time and thought. It was while he was working late at home on the satellites of Saturn in 1911 May that his health suddenly gave way. It was a relief to find him soon afterwards removing an ambiguity left in the work, and hopes were entertained of his recovery, but they were not to be realised. He died on 1916 April 16.

While devoted to his scientific work, he took a keen interest in, and was well informed upon, many of the social problems of the day.

He never married, but was a devoted brother in a large family.

He joined the British Astronomical Association in 1900, and was elected a Fellow of the Society on 1883 January 12.

[For the above obituary the Council are indebted to his friend, Mr. T. C. Hudson.]

Friedrich Robert Helmert was born at Freiberg, Saxony, on 1843 August 31; his father had an appointment in the hospital there. He attended a local school till 1857, then a school at Dresden, and subsequently the Polytechnic in the same place, which he left in 1863, having obtained a silver medal and a scholarship. Of his Dresden teachers Nagel had special influence over him, and obtained a post for him as assistant in the measurement of the Saxon arc, which he retained for three years. He then

studied at Leipzig University, obtaining his doctor's degree in 1868. His dissertation, "Studien über rationelle Vermessungen," sought how to combine the necessary accuracy in arc-measurement with the minimum expenditure of labour.

He was an assistant at Hamburg Observatory 1869–1870, and showed his love of surveying work, even in the heavens, by carrying out a triangulation of the cluster in Scutum Sobieskii. He then obtained a post as lecturer in the High School at Aachen, which he retained for seven years. In 1872 he published a pamphlet on the proper slope for curves on railways, and an important volume on the method of least squares, based on the work of Gauss, which gained for him the title of Professor. During this period he published numerous articles, *Zeitschrift für Mathematik und Physik*, the *Zeitschrift für Vermessungswesen*, and *Astronomische Nachrichten*; he also published several reviews in the *Vierteljahrschrift* of the Astronomische Gesellschaft on works dealing with problems of levelling, surveying, distribution of errors in triangulation, and the measurement of the Danish arc. In 1880 and 1884 he published his two volumes on the mathematical and physical theories of higher geodesy. On the death of General Baeyer in 1885 he was given the opportunity of putting his theories into practice, being appointed Director of the Geodetic Institute and Professor of Higher Geodesy at Berlin University. The Eighth International Geodetic Conference was held at Berlin in 1886, and the union of its Central Bureau with the Geodetic Institute was renewed, both being placed under Helmert's direction. After giving a *résumé* of the work accomplished by the institute under Baeyer, he proposed a scheme of work for determining local deviations of the vertical; a knowledge of these is necessary for combining the results of a geodetic triangulation with the astronomical co-ordinates of the stations. The results were applied to the measures of two longitude arcs, one in Latitude 52° extending from Warsaw to Greenwich, the other in Latitude 47½°.

His next work was the study of variations of gravity, by means of a pendulum constructed by v. Sterneck. He communicated in 1890 some results obtained with the pendulum at high mountain stations. In 1894 the intensity of gravity had been determined at 292 stations, including some observations made at sea. Helmert used these results, in combination with the deviations of the vertical, for investigating the constitution of the Earth's crust, and the departure of the geoid from an ellipsoid. He discussed the results at the Paris Geodetic Conference in 1900. He also took a part in the arrangement of the International Latitude Stations in Latitude 39° North, the observations of which were discussed in the Central Bureau.

Helmert was elected a Fellow of the Berlin Academy of Science in 1900, and published many important geodetical papers in its *Sitzungsberichte*. The subjects include, observations of level in surveying, with allowance for refraction: the dimensions of the

Earth, including a discussion of Hayford's ellipsoid; gravity at sea; the theory of Isostasy; the distribution of density in the Earth. His last paper, published in 1915, contains a discussion of observations of gravity made at 2112 inland stations and 325 coast stations, from which is derived a value for the Earth's compression and a formula for the intensity of gravity as a function of the latitude.

He died on 1917 June 15 as the result of a stroke, leaving a widow and one son, who is an engineer.

He was elected an Associate of the Society 1899 November 10.

Edmund Weiss was born on 1837 August 26 in Freiwaldau, Eastern Silesia. He was twin brother to Gustav Adolf Weiss, Professor of Botany at Prague. His childhood was spent in England, as his father, who was a physician, was placed at the head of a hydropathic establishment in the neighbourhood of Richmond. After his father's death he returned to his native land, and from 1847 to 1855 attended the Gymnasium at Troppau near his native town, afterwards studying mathematics, astronomy, and physics at the Vienna University. On the completion of his three-years course he was appointed an assistant at the Vienna Observatory in 1858. Two years later he gained the degree of Doctor of Philosophy.

He showed such skill and diligence as an observer and in the measurement of a meridian arc during the period 1864–67, that he was offered an astronomical post at Petrograd by Struve, and the charge of a department of the Geodetic Institute at Berlin by Baeyer. He did not accept these offers, but remained at Vienna, where he received the title of honorary professor in 1869 and ordinary professor in 1875.

Weiss visited England and North America in 1872 with the object of studying the principal observatories and optical works. He had an early opportunity of utilising the experience gained during this journey on the occasion of the building of the new observatory at Währing, near Vienna, and the purchase of new instruments, among them the great 27-inch equatorial by Grubb, erected in 1882, and an $11\frac{3}{4}$-inch equatorial by Clark, to which was added later a 15-inch equatorial coudé.

On the death of Karl von Littrow in 1878, Weiss was appointed Director of the Observatory; he retained this post till 1910, when he retired with the title of Emeritus Director.

The observations made at the observatory related to planets, comets, occultations, variable stars, and meteors.

Weiss published a large number of papers, of which a selection is noted here:—

1867. The connection between comets and meteors.

1868. Littrow's method of longitude determination by circum-meridian observations.

1869. The meteor swarm of Halley's Comet.

1873. Practical astronomy in America.

1876. The magnitudes of minor planets.

1880, 1882. Memoirs on the great comets of these years.

1886. The nebulæ in the Pleiades.

The following deal with orbit determination:—

1881. A method of obtaining the True Anomaly and radius vector in orbits of great eccentricity.

1884. Development of Lagrange's Reversion Theorem and solution of Kepler's Equation.

1893. Determination of the orbit of a heavenly body from three observations.

He also wrote many works of a popular nature, including a new edition of Littrow's *Wunder des Himmels*, and articles on the moon, comets, meteors, the dawn of astronomy, the measurement of the mid-European arc.

In 1890 he published a revised edition of Oeltzen's Catalogue of Argelander's southern zones. Oeltzen's edition had appeared in 1857. In the revision the zones were separately discussed, and systematic corrections applied where necessary.

Weiss made several journeys for the observation of astronomical phenomena. He observed the eclipse of 1861 from Greece, where it was total just before sunset; the annular eclipse of 1867 from Dalmatia; the total eclipse of 1868 from Aden, which was near the western end of the track of totality; the total eclipse of 1870 from Tunis; the 1874 Transit of Venus from Jassy.

The eclipse expeditions evince an interest in solar physics, which subsequently led Weiss to become a member of the International Union for Solar Research; he was a regular attendant at its meetings.

Weiss enjoyed a high reputation in Vienna as a lecturer, and many of his pupils were led by his lectures to take up the serious study of astronomy and do useful work in it.

He married Adelaide Fenzl in 1872, and had seven children. He died 1917 June 21 after a long and painful illness.

He was elected a Fellow of the Vienna Academy in 1878, and an Associate of the Society in 1883.

A. C. D. C.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.
(*Director, Sir F. W. Dyson, Astronomer Royal.*)

The activity of the Observatory has been limited in several directions in consequence of the war, but it has been possible to keep up all observations where continuous record is required.

Transit-Circle.—During the year 1917, 4698 transits were observed. The Sun was observed on 161 days and the Moon on 104 days. Clock stars and interior planets were observed regularly. The observation of the exterior planets has suffered slightly. The number of stars observed by reflection is only 135. The number of 12-hour groups is rather larger than usual. The number of observations of stars for the Catalogue has been very small. The reduction of the observations is in a forward state.

The Introduction for the Catalogue of Stars for 1910 (Dec. $+24^\circ$ to $+32^\circ$) has been prepared. The delay in the printing of this Catalogue makes it possible to take advantage of the kindness of Professor E. C. Pickering, who is supplying the spectral type and visual magnitude of such stars as have been observed by Miss Cannon.

The planetary results for 1915 and 1916 have been completed.

Altazimuth.—The use of this instrument has been restricted to supplementing the observations of the Moon made with the transit-circle. The Moon was observed 18 times in the meridian and 26 times out of the meridian. The mean correction in right ascension required by the *Nautical Almanac* is $+^s\cdot94$, and by the *Connaissance des Temps* (depending on the revised tables of Delaunay) is $+^s\cdot28$. The corresponding values last year were $+^s\cdot92$ and $+^s\cdot28$.

Cookson Floating Telescope.—179 plates, each exposed on a group of 4 or 5 Talcott pairs, have been taken, and 3 plates for the determination of scale. The measurement of the plates is in hand.

The Cambridge Observatory Syndicate have kindly granted the loan of the instrument to the Royal Observatory for a further period of seven years.

Occultations.—8 disappearances and 3 reappearances were

observed during the year. The results have been communicated to the Society.

28-inch Refractor.—322 double stars have been measured by M. Jonckheere, of which 166 have a separation of less than 2″. The stars observed consist of 161 from Burnham's General Catalogue, 149 taken from M. Jonckheere's Catalogue, and 12 stars newly discovered to be double.

Thompson Equatorial.—During the year 61 plates have been exposed for parallax determination, of which 49 had been exposed previously. This work has been brought to an end for the present, and the object-glass dismounted. The observations of the satellites of Jupiter, taken at the request of Dr. de Sitter, have had to be discontinued. Two photographs on one night were taken in January, and five photographs on three nights in September.

After the 26-inch object-glass had been dismounted the 30-inch mirror was resilvered and readjusted, and 9 plates have been exposed on the fainter satellites of Jupiter. The eighth satellite is well shown on three nights, and the sixth on one night.

Astrographic Equatorial.—97 plates have been taken on 29 nights. These consist of short exposures on 118 fields (usually two fields on one plate) for comparison with earlier Astrographic Catalogue plates for the determination of proper motion, 30 plates exposed for 12 minutes, taken for Mr. Innes for comparison with earlier chart plates, and 5 plates for adjustment of the instrument. Comparison in the micrometer has been made of 76 fields for the determination of the proper motion of stars in the *Bonn Durchmusterung.*

The determination of the proper motions of the stars in vol. 3 of the Greenwich Astrographic Catalogue by comparison with earlier Catalogues, supplemented by comparison of plates, is being continued.

Photoheliograph.—Photographs of the Sun were obtained with this instrument on 188 days during the year 1917, of which about 15 were days of feeble actinic power or poor definition. At the Cape Observatory photographs were obtained on no fewer than 332 days during the twelve months ending 1917 November 30, leaving 12 days unrepresented by satisfactory photographs from the combined record of the two observatories for that period; but of these, 10 days are represented in the daily series taken at Kodaikánal, which was recommenced at the beginning of April 1917.

The solar activity has continued to increase during 1917, two out of the five largest groups of spots observed on the Sun since the Greenwich photographic record was commenced in 1874, having appeared during this year, the first in the southern hemisphere in February, the second in the northern in August.

The measurement of the photographs has proceeded but slowly during the year, owing to the smallness of the staff and the great increase in the solar activity. All photographs have been measured in duplicate up to the end of November 1916, but for 1917 the photographs have only been subjected as yet to a very rough pre-

liminary examination. The mean daily area for the year may however be taken as about 1200 millionths of the Sun's visible hemisphere.

The reductions are being pressed forward as fast as possible. The entire results for 1914 have been passed for press; the Daily Results for 1915 are complete, and the Spot Ledger computed to the end of July; the Daily Results and Spot Ledger for 1916 (in a contracted form) are complete to the end of August, and the reductions of areas and heliographic positions to the end of October.

Owing to transport restrictions, no photographs have been sent from the Cape Observatory of later date than the end of February 1917.

Printing.—The Greenwich Observations for 1914, partly destroyed by fire at the printers in May 1916, are being reprinted. The astronomical part of the volume is complete, and the magnetic and meteorological section is in progress.

Personal.—Mr. Lewis retired on September 30 after a useful and distinguished service of thirty-six years at the Royal Observatory.

Last year it was reported to the Society that three junior assistants and nineteen computers were absent on military service. In April Messrs. Cullen and Melotte joined the survey section of the Royal Engineers, and in December Mr. Jackson received a commission in the same corps. Mr. Jones has continued at the Inspection Department of the Woolwich Arsenal throughout the year. Mr. Edney was at the Hydrographic Office till September, and Mr. Acton from September to the end of the year. Mr. Chapman has remained as Chief Assistant in an honorary capacity throughout the year, and Mrs. Maunder has continued her valued voluntary assistance in the solar department.

Royal Observatory, Cape of Good Hope.
(*Director, Mr. S. S. Hough, H.M. Astronomer.*)

Transit-Circles.—The meridian work of the year has been confined to the new reversible transit-circle, which has been continuously employed in connection with a programme of observations of close circumpolar stars for the purpose of a new determination of the constant of aberration. This programme was commenced in 1916 December, and will be continued sufficiently into the year 1918 to ensure considerable overlap between the early and late observations.

In the course of the year 1917 the followings observations have been secured:—

Observations of Right Ascension:—

Meridian transits of circumpolar stars . .	3695
,, ,, ,, time stars . . .	1318
Determinations of collimation by collimators	98
,, ,, level	702
Observations of meridian marks . . .	1212

Observations of Zenith Distance :—

Determinations of Zenith Distance . .	4161
,, ,, runs	598
,, ,, nadir	689
,, ,, flexure	64

Heliometer.—This instrument has been used for the observation of the major planets at the time of opposition, in continuation of programme of previous years commenced in 1897. On completion of the reduction of these observations a continuous sequence of observations of each of these planets extending over twenty years will thus be available. During the year the following observations were obtained :—

Opposition of Saturn .	16 obs. in distance	on 4 nights.
,, ,, ,, .	16 ,, ,, position angle	
,, ,, Neptune	36 ,, ,, distance	on 6 nights.
,, ,, Uranus .	48 ,, ,, ,,	on 8 ,,
,, ,, Jupiter .	48 ,, ,, ,,	on 8 ,,

Victoria Telescope and Astrophysical Laboratory.—The telescope was in use for the photography of stellar spectra on 178 nights during the year. 278 plates have been secured for the determination of radial velocities.

The programme has been confined mainly to Southern stars between magnitudes 4·5 and 5·5 of types G, K, and M, and a short-focus camera has been employed throughout. The use of this camera has made it possible to secure the spectra of fainter stars than those observed with the long camera.

202 plates have been measured for velocity on the Hartmann Spectrocomparator, which has been adapted to the smaller-scale spectra by using objectives of higher power whilst retaining the same silvered strips in the prisms as were formerly in use. The results obtained are satisfactory, the mean range of velocities obtained from two or more plates of 60 stars being 2·6 km. per second, corresponding to less than a ten-thousandth of an inch on the plates.

One of the stars observed, viz. 42 Capricorni, proved to be a previously unrecorded spectroscopic binary having a period of 13·25 days and a velocity range of 45·5 km. per second. A paper by Dr. Lunt on the orbit of this binary has been communicated to the *Astrophysical Journal.*

A further paper by Dr. Lunt on the "Radial Velocities of 60 Southern Stars" has been sent to press.

The Astrographic Telescope.—93 repetition "chart" plates of regions which had been photographed about twenty-four years ago, and of which the original negatives were still available, were secured by Mr. Wood of the Johannesburg Observatory during the month of October. These plates, together with the originals, have been taken by him to Johannesburg for comparison in the "blink" microscope of that Observatory. In addition to this, some 39

pairs of plates exposed on corresponding regions at a considerable interval of time have been sent to Johannesburg for similar treatment. The results of the measurement have been published in the course of the year in the *Union Observatory* circulars.

The instrument has also been placed at the disposal of Mr. Voûte, of Leyden, for the completion of his programme of observations for the determination of stellar parallax.

Photoheliograph.—Daily photographs of the Sun to supplement the Greenwich series have been continued throughout the year. In all 686 negatives, distributed on 333 days, have been secured. At the request of the Astronomer Royal, these have been retained at the Cape since 1917 April.

Occultations.—Twenty-nine separate phenomena of occultations of stars by the Moon have been observed during the year, viz.:—

Disappearances at dark limb . .	17
Reappearances „ „ „ . .	12

The reductions of the observations of all occultations to the end of 1917 have been completed and prepared for press.

Variable Stars.—The 6-inch equatorial has been placed at the disposal of Messrs. Long and Skjellerup for a programme of observations of Southern variable stars. They have made 333 observations of 42 stars.

Current Reductions.—All meridian observations up to 1917 December 14 have been reduced so as to exhibit mean places. During the year the ledgering of resulting right ascensions obtained from observations during the period 1912–16 has been completed and the final right ascensions computed.

The declination results have been entered to the end of 1915, the declinations for the year 1916 awaiting the results of the determination of the variation of latitude from the international stations.

The observed right ascensions of the Sun and of the planets Venus and Mercury to the end of 1916 have been entered in ledgers, and the corresponding tabular right ascensions and declinations computed.

In connection with the Cape Astrographic Zones, the revision work, including comparisons with the C.P.D., has been completed, and the final copy for press of the rectangular co-ordinates and diameters of stars formed for all zones. Printing of results has been suspended during the war. Counts of stars grouped according to magnitude have been made for the Zones $-44°$ to $-51°$.

Four papers arising out of the discussion of the problem of the determination of stellar magnitudes by photographic methods have been communicated to the Society.

The rectangular co-ordinates of all standard stars contained on plates whose centres lie on the Zones $-41°$ to $-48°$ have been revised by the application of magnitude corrections and plate-constant corrections derived from a reconciliation of overlapping areas. The co-ordinates thus obtained have been converted into

right ascensions and declinations, which have been ledgered with the view to the formation of a revised catalogue of the places of these stars based on a combination of the meridian and photographic results.

Miscellaneous.—The time-signal service, meteorological observations, and seismograph records have been maintained as in previous years.

Royal Observatory, Edinburgh. (*Director, Professor R. A. Sampson, F.R.S., Astronomer Royal for Scotland.*)

General.—Astronomical work continues under severe disabilities imposed by war conditions. Mr. Storey and Mr. Wrigley have been absent throughout the year on Admiralty service.

Miss S. A. Falconer has left to engage in war work, and has been replaced by Miss K. A. Williams.

The work which it has been possible for the reduced staff to do has been further impeded by the difficulty of obtaining instruments, materials, or repairs.

Transit-Circle and Clocks.—Full attention has been given to time keeping and time determination generally. The three clocks, Riefler, Synchronome (Shortt's escapement), and Cottingham (Gill's escapement), have been kept under close observation, and their records are under analysis. A second Synchronome clock has been obtained on loan from the Synchronome Company in order to make experimental variations in its features, and some changes have been introduced in it in order to trace the source of certain faults of going in the first. The first continues to show an acceleration of rate of about $-0^{s}\cdot016/(\text{day})^{2}$; this feature does not show in the second clock. Mr. Cottingham's version of Gill's escapement has continued to work without default after certain initial adjustments were made. All these clocks, though not at present so perfect and reliable in time keeping as Riefler, show promise that they may become so, and are much simpler and cheaper to make. Experiments on the temperature compensation have been made twice, by letting down the temperature of the thermostat chamber and raising it again after an interval of several days. These confirm one another in the conclusion that all the clocks are seriously under-compensated for temperature changes.

The microchronograph, to which reference was made in the last report, has been developed into a working instrument, with which relative times are now taken every day. It is abundantly proved that these determinations are accurate to $0^{s}\cdot001$. A paper is in preparation describing the method and results.

A series of studies upon all points connected with clocks and time keeping is being written. The first of these, on the theory of the maintenance of motion, containing also many

particulars as to the installation, was read before the Royal Society of Edinburgh on 1918 January 14.

Wireless Time-Signals.—The rhythmic time-signals from Paris have been taken on 133 nights, and the results of the comparisons with our own clocks telegraphed to the Observatory of Paris. The mean difference has been found = *Paris—Edinburgh* $+0^{s}\cdot03$, compared with $+0^{s}\cdot02$ in 1916 and $+0^{s}\cdot05$ in 1915.

Solar Spectroscope.—Exposures were made upon the Sun's limb, East and West, at the Equator, in the neighbourhood of λ6300, for continuity of determination of the solar rotation. The plates seemed to be inferior in sensitivity, and the results are not up to the previous standard, but will prevent a gap in the series.

Photo-electric Work.—Mr. Baker has devoted a large share of his time to this work, and has constructed several cells of good quality. Progress would have been greater but for the impossibility of obtaining requisite material. Good advance and some valuable studies have, however, been made, especially upon the phenomenon of the "dark" current.

Astrographic Chart.—An examination of the magnitudes estimated in the common way from the diameters of the images, compared with those estimated at Perth, W.A., by a standard eyepiece scale of graded images, led to the conclusion that the latter method was much more consistent and significant than the former. A revision of the magnitudes has been begun upon this plan, and is advancing as time allows.

Seismograph.—Observations have been made regularly with the Milne seismograph, the sheets examined and readings communicated to Shide. Great improvement in the trace has been made by discarding the crossed slits and substituting a very small short focus lens forming a sharp, minute image on the sensitive paper.

Meteorological Observations have been made as heretofore. A Dines microbarograph has been set up, working in conjunction with Eskdalemuir Observatory. A copy of this, with some variations of detail, has been constructed in the Observatory workshop, and shows what promises to be better and bolder traces.

Armagh Observatory.

Dr. Dreyer resigned his position as Astronomer at Armagh Observatory on 1916 October 1. The Astronomer appointed in his place, Mr. J. A. Hardcastle, died before taking up his duties, so the only work done at Observatory during 1917 has been meteorological.

Cambridge Observatory. (*Director, Professor A. S. Eddington.*)

It was stated in the last report that both the assistants were absent on war service; during the year both have lost their lives. Mr. W. E. Hartley, Naval Instructor, was killed by the explosion

of *H.M.S. Vanguard* on July 9. Second Lieutenant F. Entwistle was killed in action in France in October. The Observatory has suffered a great loss, which will be felt the more keenly when the time comes to resume the normal course of work.

The death of Mr. Hartley has necessitated some alterations in the plan of work. Fortunately he had completed, a few months before his death, a task on which he had been engaged for many years—the publication of the ledgers of observations for the Cambridge Zone Catalogue (1875·0), including the revision observations made in 1898–9. But he was also engaged on observations for a Catalogue of Zodiacal Stars (according to the programme arranged by Sir David Gill), and now that the intervention of another observer is inevitable, it has seemed important to make an effort to complete this Catalogue, which had already spread over a longer period than was desirable. The Catalogue is practically fully observed (five observations for each star) except for the intervals $0\frac{1}{2}^h$–$4\frac{1}{2}^h$ and 9^h–16^h R.A., where some bad gaps occur; but it is hoped to secure a minimum of three observations for every star and close the Catalogue next summer. Since October observations have been made on 12 nights; 249 observations in R.A. and 243 in Dec. have been obtained. Some progress has been made with the reductions; the star-constants are many years in arrear, but the reductions to apparent place have been brought practically up to date.

Demonstrations in practical astronomy at the Observatory were given during the Lent and Easter terms, but were suspended during the Michaelmas term owing to the necessity of devoting as much time as possible to the Zodiacal Catalogue at this particular period. By the kind assistance of Mr. J. A. Aldis and Mr. C. P. Butler the Saturday evening exhibitions of celestial objects with the Northumberland Equatorial have been continued, but the weather has been particularly unfavourable.

Solar Physics Observatory, Cambridge University.
(*Director, Professor H. F. Newall.*)

Spectroheliograph.—Photographs of the Sun's disc in K_{2-3} light have been obtained on 151 days (previous year, 108), and photographs of the prominences at the limb on 144 days (previous year, 92).

The definition of the photographs has been in general less good than usual, but a few days of exceptionally good definition have occurred from time to time. Many of the records have only been obtained by seizing opportunities afforded by short intervals of clearness between clouds.

The solar activity does not yet appear to be decreasing; for after short periods of comparative quiescence, there have been recurrences of spots, flocculi, and prominences on a scale corresponding with maximum activity.

For the year 1916 October 1–1917 September 30 the Director of the Kodaikánal Observatory has sent 333 spectroheliograms showing the solar disc in K_{2-3} light. Of the 32 days missed in the Kodaikánal record during this period the Cambridge record has photographs for 13 days.

The spectroheliograms from Kodaikánal for 81 days during 1916 July, August, and September were lost by the torpedoing of a mail boat. The Cambridge record has photographs for 44 days in these months. It is hoped that copies may be obtained from the negatives retained at Kodaikánal.

Photoheliograms.—Daily photographs taken with the photoheliograph at Dehra Dûn have been received, and the negatives are stored at the Science Museum, South Kensington. Positive prints have also been received from Dehra Dûn. A batch of original negatives in this series have been lost by the torpedoing of a mail boat, and these cannot be replaced.

Spectra of Sun-spots.—Many photographs of spectra of sun-spots, chiefly in the region 5300–5500, were obtained in the autumn with the McClean Solar Instruments. A few records have been secured in the region 4200–4400 for special study of the behaviour of the hydrocarbon bands in that region. So far as the evidence goes at present, these bands are hardly affected in the spectra of sun-spots.

Arrangements have been successfully developed for securing photographs of the Sun's disc with the 60-feet lens of the same installation. They are taken on slow bromide paper, and afford excellent records of the distribution of the spots, etc., which have been studied spectroscopically.

Comparison tables of published lists of affected lines in sun-spot spectra in the region 3900–7165 have been compiled. In these published lists the chemical origins are based by the various observers almost entirely on the identifications in Rowland's Solar Tables. The identifications have been revised and considerably amplified by reference to more recent work in the laboratory. By study of Hale's preliminary photographic map (1907) of sun-spot spectra a complete review has been made of the affected lines throughout the region 4600–7165, and has furnished many new lines and identifications. A considerable amount of time has been devoted to a search for origins of some of the bands occurring in sun-spot spectra other than the well-known bands ascribed to titanium oxide and the hydrides of calcium and magnesium, but no new identifications have been found.

Stellar Spectra.—All the Cambridge stellar spectra assignable to the types and sub-types F to Mb of the Harvard classification have been reviewed with the object of finding a continuous sequence. The differences of detail in spectral characteristics have been studied in their chemical relations, special attention having been given to the greater or smaller prominence of the hydrocarbon bands, and in particular the group of lines at 4324 which occurs in that spectrum. It would appear that, other characteristics being

equal, the absence of the hydrocarbon groups may be taken as a sign that the star belongs to an early sub-type of F, and that only in the later sub-groups of F stars do faint traces of this band appear. As an instance of the application of this criterion, α Persei would belong to an earlier sub-group than α Canis Minoris, though both stars are usually assigned to the same type F5.

A series of 37 photographs of the spectrum of β Lyræ taken in 1892–5 has been studied with special reference to an attempt to assign different lines to separate components in a system consisting of two or more stars.

Work in the Laboratory.—Work is being continued in the study of the carbon compounds. Special attention has been paid to the localised spectra of positive and negative poles as distinct from the mid-gap spectra.

Investigations in Atmospheric Electricity.—The method already described (*Roy. Soc. Proc.*, A, 92, 555) for the quantitative investigation of the electrical phenomena of the atmosphere, with the addition of apparatus for obtaining photographic records, was applied to the study of a number of thunderstorms during the summer months. A large series of records was obtained of the sudden changes produced in the electrical field by the passage of lightning discharges at various distances—the beginning and end of the thunder being also in many cases recorded by a momentary interruption of the trace. The records indicate the existence of several remarkably definite types of discharge. Many cases were recorded in which the electrical field at the place of observation was suddenly changed or reversed many times in the course of a second. The records are being measured and discussed and prepared for publication.

Staff.—Four members of the staff are still absent on war duties.

Dunsink Observatory. (*Director, Professor H. C. Plummer, Royal Astronomer of Ireland.*)

The general state of the sky during 1917 was even more unfavourable than in the previous year, and the total number of moderately fine nights fell to 47. As this includes the nights with bright moonlight and the short nights of the summer months, the photographic work done with the reflector has naturally been below the average. The number of plates taken was 153. On the other hand, 322 plates have been measured, including the independent measurement of a region on the long series of χ Persei plates in the possession of the Observatory. This gives a determination of the magnitude of the variable B.D. $+56^{\circ}\cdot547$ over a period of four years. These results, and a discussion of the light curve of the 7^{h} variable RZ Cephei, have been communicated to the Society.

The time-service to Dublin has been continued without change. Clock error was determined with the meridian circle on 76 nights.

Minor repairs to the shutters of the South equatorial dome became necessary early in the year, and were carried out.

There has been no change in the staff.

Glasgow Observatory.
(*Director, Professor L. Becker; Assistant, James Connell.*)

The Director has been on leave of absence throughout the year, and the usual routine work connected with the time-service and meteorological observations has been carried on by the Assistant.

In addition to the above, the Assistant has had under his care a number of chronometers and watches belonging to the Admiralty; these were compared daily with the Standard Mean Time Clock, and their errors and rates derived.

Liverpool Observatory, Bidston.
(*Director, Mr. W. E. Plummer.*)

The hampering restrictions imposed by Police regulations, mentioned in the last report, are still enforced, and the activities of the Observatory are proportionately reduced. Further, the Meteorological Office needs observations at unusual hours for the purpose of weather forecasts for military purposes, and the supply of this information not only places an additional burden on the small staff, but tends to give to the work of the Observatory a decidedly meteorological direction.

The routine observations connected with the distribution of time-signals and for rendering other services to the Port are continued with regularity. In this connection it may be mentioned that the deviations between the observed and predicted height of tides point to the necessity of employing new values of the harmonic constants in the computations. The addition of new docks, the provision of protecting channels, and extensive dredging make a re-examination of the constants desirable, and this work is being prosecuted during the enforced curtailment of regular astronomical observations.

The seismological observations are continued without interruption, but these have little connection with the astronomical work properly so called.

Radcliffe Observatory, Oxford.
(*Director, Dr. Rambaut, Radcliffe Observer.*)

Difficulties of various kinds have hampered and restricted the work of this Observatory during the year 1917. The staff, which had been reduced from four to three by the absence of Mr. Balk on military service, was for the greater part of the year still further diminished by the prolonged illness of the first assistant, Mr.

Wickham. The Director was thus left with practically only two assistants (viz. Mr. Robinson and Mr. Barrett), a large proportion of whose time was occupied with the meteorological observations and reductions which were carried on without interruption. Other difficulties of a practical kind, arising out of the present war conditions, still further disturbed the routine of astronomical duties and curtailed the output of work in this department.

As far as possible the programme of work with the 24-inch photographic refractor, on Professor Kapteyn's "Selected Areas," was continued as before, and at the end of the year only four of these areas remained to be photographed. Of these one lies in 5 hours, two in 8 hours, and one in 10 hours of R.A.

Thirty-seven proper motion photographs were taken during the year, of which eight proved to be imperfect or incomplete, leaving twenty-nine plates which were considered satisfactory for the purpose in hand. Twelve plates, exposed but not developed, are ready to be packed away, which will make thirteen dozen proper motion plates now stored in this manner.

The 10-inch Barclay equatorial was used by Mr. Barrett for observations of the variables which he has had under investigation for some years past. Owing to various causes the number of observations of these stars is less than usual. The star 5, 1913 Arietis was not observed, but of the other three, namely, ST Draconis, VV Aurigæ, and 4, 1913 Tauri, 56 observations (129 comparisons of brightness) have been secured.

The work of completing and preparing for press the results deduced from parallax plates taken in recent years with the 24-inch refractor has made but little progress owing to causes already referred to.

The investigation into the possible causes depending on star-magnitude affecting some of the values of parallax, mentioned in the report of this Observatory for last year, has been completed, and as a result a table of corrections has been formed in order to eliminate as far as possible the effect of this error.

The copy for press of this Catalogue, which contains results for 2406 stars, is nearly complete, requiring only the final revision and the Introduction. There are, however, difficulties about having it printed under present conditions.

Volume lii., part i., of the *Radcliffe Observations*, containing the results of meteorological observations made during the year 1916, was printed during the summer, and a limited number of copies distributed in the usual manner.

University Observatory, Oxford.
(*Director, Professor H. H. Turner.*)

The reduction of the Vatican plates for the Astrographic Catalogue has proceeded only slowly, owing to the limitation of supply of measures from Rome. Zone $+58°$ is now fully

reduced, and some measures in $+57°$ have been received. The whole of Vol. III. (Zone $+62°$) is now in type, and its issue is expected shortly. The computer engaged on this work has thus been able to measure several plates in Zone $-22°$, which were sent from the Santiago Observatory in response to a suggestion. It is hoped that funds may be found for dealing with the whole of this zone, and thus expediting this part of the Catalogue, which is at present in arrear.

The meteorological investigations have been further developed. Mr. Bellamy's analysis of the daily barometer readings at the Radcliffe Observatory, Oxford, 1853–1915, led to the conclusion that the differences between corresponding calendar days in "even" and "odd" chapters were of an accidental character, and the same held for short series of two, or ten, or even twenty days, but that a systematic difference was clearly manifested for longer periods. Other investigations are proceeding, but nothing has been published during the year.

The Director has continued his superintendence (with the able co-operation of Mr. J. J. Shaw) of the seismological work at Shide. The quakes of 1913 have been collated and discussed along with those of 1914. The anomalies near the epicentre suggested in the last report were not confirmed; but a fairly satisfactory set of tables for P and S has been derived, and will now be tested. The discussion will appear in the Twenty-second Report to the British Association.

The editing of Baxendell's observations, in collaboration with Miss Blagg, was completed as originally proposed; but is being extended by the addition of a few more stars, perhaps less well observed than those formerly selected, but still worth attention.

The value of the galactic condensation approximately estimated in 1915 from the Astrographic counts has been confirmed and given precision by an investigation by Mr. F. H. Seares. The counts can thus be cleared from its effects, for the study of the "spiral," and this has been done for two zones (Cordoba $-25°$ and Tacubaya $-15°$) in a paper communicated to the Society in November, as well as for several other zones in hand. Ten zones visually observed at Cordoba ($-52°$ to $-62°$) were also discussed, and found to give results accordant with the "spiral."

There have been no students during the year, but various lectures have been given to troops. The Director spent some weeks in France early in the year for this purpose.

The Coats Observatory, Paisley.
(*Convener, Rev. Chas. A. Hall, F.R.M.S.*)

Throughout 1917 the usual work of the Observatory—astronomical, meteorological, and seismological—has been carried on regularly. The several instruments have been kept in good order.

In pursuance of a requisition by the Lords Commissioners of

the Admiralty for all chronometers not actually in use for navigation, the valuable chronometer belonging to the Observatory has been sent to the Admiralty.

Owing to increasing pressure of professional duties Dr. Ferguson has found it necessary to retire from the post of Convener, and the Rev. Chas. A. Hall, F.R.M.S., has been elected to succeed him.

Imperial College, South Kensington. (*Professor A. Fowler.*)

The astronomical instruments were used mainly for teaching purposes, but occasionally also for the observation of sun-spots and solar prominences.

Experimental investigations of the spectra of silicon, carbon, and oxygen were continued as opportunities occurred, and an account of some of the results for oxygen, in relation to stellar spectra, has been communicated to the Society (*M.N.*, **77**, 511). In collaboration with Professor Strutt, an investigation of the absorption spectrum of ozone was undertaken, and it was demonstrated that certain bands in the ultra-violet spectrum of Sirius are produced by the ozone contained in the earth's atmosphere; the same bands appear also in the spectra of other stars, and in the solar spectrum, their intensity increasing as the altitude diminishes (*Roy. Soc. Proc.*, **93**, 577).

In another investigation, undertaken in collaboration with Mr. C. C. L. Gregory, research student, the ultra-violet band of ammonia having its maximum at λ 3360 was photographed with high dispersion and shown to be present in the solar spectrum. A further investigation resulted in proving that the water-vapour band λ 3064 is also present in the solar spectrum. Papers dealing with these spectra have been communicated to the Royal Society.

A considerable amount of time was devoted to work arising out of the war.

Stonyhurst College Observatory.
(*Director, Rev. W. Sidgreaves, S.J.*)

The meteorological, magnetic, and seismological observations have been carried on as usual.

Observations of the solar surface made on 210 days include 211 drawings on 208 days, and notes without drawings on 2 days. Of the drawings 171 are complete, showing all spots and faculæ, and the remaining 40 are incomplete, showing all the spots, but without a record of the faculæ. The visible disc was never found spotless throughout the year.

The mean disc area of the spots (in units of 1/5000th of the visible surface) was 12·1. This value is about three times greater than that of the previous year (1916), and twice as great as at the previous maximum, 1905–6. The increased activity commenced early in February, and reached its greatest intensity in August,

in which month the mean area was 25 units, or about double that for any other month of the year. The most active period was about August 6–16, during which the mean area was 40 units. The greatest area of any one day was 50 units, on August 11. The February and August groups were of exceptional size, and were second to none that have appeared on the Sun for the last 38 years.

With reference to the comparison of drawings of faculæ and spectroheliograms alluded to in our last report, we have received from the Mount Wilson and Yerkes Observatories, through the courtesy of Professor Hale and Professor Frost, some spectroheliograms in calcium K_2 and H_α radiations. A preliminary comparison of the drawings of the faculæ and the photographs of the flocculi show an almost perfect agreement between the faculæ and the calcium flocculi, but no similarity with the hydrogen flocculi.

The spectra of a few spots were observed, to keep up our record.

A few spectra of stars were also obtained with the Thorp prismatic camera.

Various calls have been made for popular lectures on astronomy to the troops in home camps, which have been gladly met.

Mr. A. A. Buss's Observatory, Chorlton-cum-Hardy, Manchester.

Telescopic and spectroscopic observations were made on 120 different days during the year on the same lines as those which have been carried on since 1895. The observations suggest that the maximum of the present spot cycle may not yet have been passed, for as late as December 25 no less than 18 different spots and groups of spots were visible on the Sun's disc, and some of them were spectroscopically very active. Moreover, throughout the year there were many fine displays of phenomena in the atmosphere as well as on the disc. There were also numerous examples of dark hydrogen flocculi, or their brilliant prototype in the form of prominences, seen projected on the disc, and of dark masses seen projected upon the luminous portion of prominences on the limb. Absorption effects in helium D_3 were frequently observed between the chief components of active spot-pairs, and also over merely faculic areas. Many beautiful exhibitions of deflection-effects and motion-forms, particularly easily discernible in H_α, and numerous instances of the "claw" effect, were noted.

The 6-inch Simms object-glass, which was kindly lent to me by the Society, has been mounted in woodwork on the equatorial stand which carries the $3\frac{1}{8}$-inch Bardou refractor, the two telescopes being interchangeable in a few seconds. While the larger aperture gives a little greater detail in some of the prominences, and perhaps renders the chromospheric lines somewhat more visible, it does not yield the crisp, clear-cut images of the smaller telescope.

Experiments were also made as to the suitability of silvered film-replicas of gratings for solar observations.

Wolsingham Observatory, Tow Law, Co. Durham.
(Rev. T. E. Espin.)

The search for new double stars in the selected zones has been steadily pushed forward during the year. In the autumn the 17¼-inch was remounted on a rough equatorial stand of the Old English form, and has been employed in the hands of Mr. W. Milburn in continuing the search for new doubles in the selected zones. As there is at present no driving clock for the 17¼-inch, the stars found double have been measured with the 24-inch. Micrometrical measures of various stars have also been made, mostly of stars that have been hitherto neglected. The results of the year's work have been communicated to the Society.

Mr. A. M. Newbegin's Observatory, Wallington, Surrey.

The 6¼-inch Cooke photo-visual telescope has been used solely for solar observations throughout the year, with the 3-prism Evershed spectroscope. The results for prominences recorded are set forth below:—

Number of observations	= 126
,, prominences	= 1962
Daily average	= 15·57
Daily average height	= 46″·84.

Distribution:—

Prominences in N. hemisphere	= 1023
,, S. ,,	= 939
,, E. limb	= 1002
,, W. ,,	= 960
,, under 30″ in height	= 500.

Metallic prominences were recorded on 96 days in 161 outbursts. By far the greater number fall into Class I., and very active disturbances of Class III. were observed on eight occasions. Dark absorption markings on prominences were occasionally noted.

The results indicate a decided northerly preference compared with the previous year, and the excess is again on the east limb.

Many very fine prominences of special interest were observed, and notes on their behaviour are preserved in the records. Coupled with the increased daily average is that of increased height, and it is noteworthy that the average height was remarkably uniform throughout the year.

During part of the year Miss E. Brander has been receiving instruction in the use of the spectroscope and in the general work of the Observatory.

Mr. G. J. Newbegin's Observatory, Lyndale, Sutton, Surrey.

Taking the year 1917 as a whole, the atmospheric conditions have been decidedly more favourable for Prominence observation.

Seventy-eight observations for Solar Prominences were made, resulting in a total of 835 Prominences, of which an increased number were of greater elevation and were more widely distributed in latitude than in the previous year; those classed Bright are very much in excess of those classed Faint. The tendency northward was more pronounced than in the previous year.

The mean daily average works out at 10·7, as against 8·3 in the previous year.

Rousdon Observatory, Devon.
(Sir Wilfrid Peek's; Mr. C. Grover, Observer in Charge.)

The building is kept in good repair, and the equatorial is in perfect working order. Weather has been fairly good for observations, but during the first three months severe frost on several fine nights made observations impossible. April, September, and October were the best observing months. Observations were made on 134 nights. Observations of the long-period variable stars have been continued on the same lines as in former years, and 423 magnitudes were determined, making a total of 13,692 magnitudes during the thirty-two years this work has been in progress. 494 maxima and 353 minima have been observed. These figures show about the average amount of work done, and several variables showing well-marked irregularities have been diligently observed.

Observations with the transit instrument are frequently taken for regulation of the sidereal clock, which maintains a very satisfactory rate. The usual meteorological observations have also been regularly continued.

The Rev. T. E. R. Phillips's Observatory, Headley, Epsom, Surrey.

Absence in France and other causes interrupted the work at the beginning of the year. Subsequently the usual observing programme was followed, consisting mainly of observations of the planets and double stars.

The 18th Report of the Jupiter section of the British Astronomical Association, dealing with the observations made during the apparitions of 1914 and 1915, was published during the year.

Special attention was paid to the binaries *ξ Boötis* (Σ 1888) and 70 *Ophiuchi* (Σ 2272), 25 sets of measures being secured of each pair. *ξ Boötis* apparently exhibited a striking irregularity of motion

in 1917, the position angle remaining stationary after changing rapidly during recent years. Irregularities have been observed before, and there is probably some source of disturbance which has not yet been traced.

The meteorological observations have been continued.

In August the 18″ silver-on-glass reflector, bequeathed to the B.A.A. by the late Mr. N. E. Green, which has been lying unused for some years, was erected at Headley for the use of members of the Association. The mirror, which is by G. H. With, is found to be a very fine one. It is mounted in a square wooden tube on an equatorial of the English form. It is hoped shortly to supply it with a clock movement.

Mr. W. H. Steavenson's Observatory, West Norwood.

It was not found possible to attempt much in the way of regular work during 1917, but a certain number of observations of selected objects was made, more especially in the early part of the year.

Very little planetary work was done, though a few observations of Tethys and Dione, showing marked variability, were made.

The comets Mellish, Schaumasse, and Wolf were well observed. The last named showed practically no change in brightness during a period of over four months.

Barnard's star of rapid proper motion was examined several times for variability, previously suspected; but no certain evidence of this was found. Owing to peculiarity of colour and the proximity of a bright star, estimates of its magnitude were apt to vary somewhat according to the time of observation, the type of telescope employed, and the power used.

The 15-inch reflector was employed chiefly in the observation of faint objects, such as the variables SS Cygni and R Coronæ at the times of minimum.

Nova Persei was found to be still variable to the extent of about one magnitude, the mean brightness being approximately 13·5. The nebulous glow surrounding the Nova, first seen in 1916, was still conspicuously visible in 1917 October.

Helwân Observatory, Ministry of Public Works, Egypt.
(*Superintendent, Mr. H. Knox-Shaw.*)

The Reynolds Reflector was not used during the year except on three nights in January, and no work of an astronomical nature was done except the maintenance of the time-service and the taking of observations of solar radiation. The same meteorological, seismological, and magnetic observations were made as in 1916.

Kodaikánal and Madras Observatories.
(*Director, Mr. John Evershed.*)

The Observatory has temporarily lost the services of Dr. Royds, who volunteered for military training in November 1916, but continued his work at the Observatory until October 1917, when he was appointed Assistant to the Director of Ordnance Factories, Calcutta. First Assistant Sitarama Ayyar has been appointed Assistant-Director substantive *pro tempore* from October 24.

The routine photographic and visual work of the Observatory has been continued as in former years, but the weather conditions have been exceedingly unfavourable for all classes of work. The photographic records have consequently suffered, but more in quality than in quantity.

Grating Spectrograph.—This instrument has been greatly improved for work requiring long exposures by surrounding and covering the grating chamber with closely-packed sandbags. A telescope with collimating lens has also been added for reading a sensitive thermometer, the bulb of which is inserted in the grating chamber. The temperature since this improvement was effected has been remarkably constant, and a change exceeding 0°·01 F. seldom occurs in a two-hours' exposure. The instrument has been used for various researches connected with the general displacement of the lines of the solar spectrum with reference to the arc lines. Two series of photographs have been obtained for the spectrum of Venus with Fe arc comparison lines, and of control plates of daylight and Fe arc. These are for discovering whether the general shift towards red of the lines at all points on the visible disc of the Sun affects also a hemisphere of the Sun turned 90° or more from the Earth. If there is no difference of wave-length in the light reflected by Venus, when corrected for motion, and ordinary sunlight, then the displacements observed cannot be interpreted by motion alone; whilst if the Venus spectra show a smaller wave-length, an Earth effect is involved. This work was almost blocked by the heavy monsoon conditions, some idea of which may be gained from the fact that during four whole months, between June 1 and October 1, no single evening was clear enough for any photographic work on Venus, and during October and November the work was rendered extremely difficult by the almost constant presence of cloud. After much wasted effort, five good Venus and Fe arc spectra were secured during October, but the angle Venus-Sun-Earth had then become reduced to about 62°. Measures of these show a small, but apparently trustworthy, difference of wave-length compared with the control plates, and confirm the results of the earlier series of plates obtained in February, which show a distinctly smaller wave-length for the iron lines of the Venus spectrum compared with the same lines in the control plates. The results, therefore, favour the motion interpretation of the shifts, involving an Earth effect, but there is some doubt whether the February plates

are entirely free from error due to "pole effect" in the arc. It is hoped to obtain a third series of spectra in the morning skies of June and July 1918, when the conditions may possibly be more favourable, and may admit of a decisive result.

Dr. Gilbert Walker has suggested that the law of increase of shift of the solar lines from the centre of the disc to the limb, as observed at Kodaikánal, might be explained on the hypothesis of a constant "relativity" shift towards red, combined with a shift towards violet due to a radial outflow of the gases of the reversing layer. This violet shift would decrease from a maximum at the centre to zero at the limb, where the "relativity" effect would have its full value. Relativity, however, will not explain the limb – arc shifts completely, for many lines have shifts exceeding the theoretical gravitational shift equivalent to 0·634 km/sec. Also, any such residual shift at the limb cannot be assigned to motion without implying an Earth effect.

It is hoped that the Venus spectra will eventually decide whether the Sun's gravitational field is concerned in the solar line-shifts or not.

The Venus plates have also been used to determine the relative velocity of Venus and the Earth, taking account of the Earth's diurnal movement. The greatest displacement with a dispersion of 1 mm. = 1·4 A is 0·14 mm., and it has been found that measuring the double interval by the positive on negative method the probable error of a displacement determination averages one part in 400 for a single plate of 40 lines. By combining the results from east and west elongations of the planet the possible difference of wave-length between the direct and the reflected light is eliminated, and the velocities may then be compared with the values obtained from *Nautical Almanac* data, and a correction may be found to the adopted solar parallax. A preliminary result from the first and second series of plates indicates a very small correction, which may be considered as a guarantee of the reliability of the plates for the wave-length determinations.

It is to be noted that the Venus plates were taken when the phase of the planet was considerably greater than half, and it is important to remember that a possible source of error becomes serious when the phase is less than half, for if the planet rotates about an axis approximately perpendicular to the orbit plane the light will then be taken entirely from the approaching or receding side of the disc. In a plate exposed on November 28 (the only plate obtained at half phase or less) the observed velocity is 0·46 km/sec. less than the theoretical velocity, and it is difficult to explain this large discrepancy except by supposing that Venus rotates in the same direction as the Earth and with the same order of velocity.

In comparing Venus and Fe with sky and Fe plates, taken under apparently identical conditions, precautions have to be taken against shifts of the arc lines due to "pole effect," and to the effect of exposure time on slightly unsymmetrical lines. During the

monsoon months investigations were undertaken with a view to testing the stability of the Fe lines under various conditions. The sensitiveness to pole effect has also been determined for all the lines used in the Venus spectra. In this work the positive on negative method was found to be invaluable for detecting and locating in the arc small shifts of 0·002 A or over without the labour of measurement.

Amongst other results connected with Sun – arc measurements, reference may be made to some measures of spectra obtained by Dr. Royds in the region, including the telluric oxygen lines of the *a* group. These have been measured in order to test the observation reported by Pérot, that the telluric oxygen lines of the B group indicate a motion shift, amounting to 3 km/sec. in a direction normal to the Earth's surface. Our result, from high and low Sun spectra, gives an entirely negative result. The oxygen lines appear to be absolutely fixed with reference to the arc lines of iron.

Star Photography in Daylight.—At the request of Mr. Lindemann an effort was made to observe the conjunction of Regulus and the Sun on August 22 by the photographic method initiated by him. Light from the siderostat was passed through two large prisms placed 35 feet apart and in reversed positions, the second prism taking up and recombining only the red rays, which then entered an 8-inch telescope. The more refrangible red rays were cut out by an absorbing screen placed near the focus. As the Sun would be in the field of the telescope together with the star, an arrangement was constructed whereby the Sun's image could be reflected out of the tube during the exposure on the star, yet admitting of an instantaneous exposure, so that a record might be obtained of both Sun and star on the same plate. Measures of the distance of the star from the Sun's limb would then be used to discover whether there was any displacement of the star due to the gravitational field of the Sun.

The day of conjunction was not clear enough to test the method satisfactorily, and no star image appeared on the plates obtained, nor could the star be seen visually during fairly clear intervals.

Solar Radiation. — A series of measures was obtained by Dr. Royds with the Ångström pyrheliometer during the fairly clear weather of the dry season. These appear to show that the value on the solar constant was falling from February to May.

Interferometer.—Dr. Royds has constructed and made experiments with interference standards of the pattern of Fabry and Pérot with a view to their use in determining solar line displacements with great accuracy. His apparatus is ready for mounting in front of the spectrograph when observing conditions are favourable.

Publications.—Vol. i. part 2 of the *Observatory Memoirs* and five Bulletins were published during the year, but under instructions from Government only a few copies were distributed privately outside India.

Visitors.—The Observatory was visited during the year by a tigress and two cubs. They arrived by the north meridian mark, and killed a cow at the well.

Madras Observatory.—The transit-circle was employed for the time-service of India as in former years. Some observations made with the 8-inch telescope indicate the excellent effect on the midday definition of the proximity of the sea, confirming observations made in New Zealand and Australia.

Nizamiah Observatory, Hyderabad, Deccan.
(*Director, Mr. R. J. Pocock.*)

The astrographic work has made good progress during the year. The total number of plates measured during the year is 211, containing 65,877 stars, which, with those measured in previous years, makes a total of 533 plates, containing 181,107 stars.

Zone $-17°$ was complete a year ago; the whole of the proof has now been passed for press, and the volumes should be ready for distribution almost immediately.

Zone $-18°$ is now complete, the 180 plates in this zone containing 61,379 star images, an average of 341 stars per plate. The whole of this volume is in the printers' hands, and the proofs, as far as 18^h, have been passed for press, so that this volume should also be ready for distribution at an early date.

In Zone $-19°$, 132 plates have been measured during the year, containing 46,318 star images. These have been copied for press, but not yet sent to the printers. In addition to those measured, 18 other plates in this zone have been taken.

In Zone $-20°$ the standard co-ordinates have been computed during the year, and the tables for this zone are nearly complete; 67 plates have been taken, of which 41 plates, containing 9974 stars, have been measured; 34 of these plates have been copied for press.

The astrographic work has absorbed the attention of the staff to such an extent that practically no other work has been possible during the year.

The Dominion Observatory, Ottawa, Canada.
(*Director, Otto Klotz.*)

Meridian Work.—Observations with the Meridian Circle were obtained on 105 nights; they were devoted in part to determination of clock error for longitude work and the purposes of the time-service, and in part to a continuation of work on the list of latitude stars mentioned in previous reports. Three observers took part in the work. The printing chronograph was used throughout the year for the registration of transits.

Field observations for latitude and longitude were carried

out at one station on the boundary between British Columbia and Alberta. A 3-inch Cooke astronomical transit, fitted with registering micrometer and latitude level, was used for the field observations; Ottawa was the base for the longitude determination, the exchange of time-signals being along 3000 miles of continuous wire.

The time-service has been maintained as in previous years. The system of clocks controlled from the Observatory was extended to include a group in the Government Printing Bureau, formerly independent. There are now nine secondary master-clocks synchronised continuously from the Observatory; these in turn control 375 clocks and dials of various kinds. In addition, relays beating seconds are maintained in two offices in the city, time-signals are sent out by telegraph and telephone, and the time is recorded on the various seismographs at the Observatory.

Astrophysics.—During 1917 the 15-inch equatorial has been employed, as formerly, in the determination of the radial velocities of spectroscopic binary stars with a view to securing the elements of their orbits. A total of 428 plates was secured with the single-prism instrument, making a grand total of 8403 plates to the present. For most of the year two observers only were engaged in the work, the stars spectrographed being on the average of about 5·6 photographic magnitude. Eight orbits were completed during the year, making a total to date of fifty from this Observatory. Those completed this year were the following:—20 π Cassiopeiæ, π Arietis, 40 Aurigæ, 29 Canis Majoris, Boss 3138, Boss 3511, Boss 5996, Boss 6142. On three of these the secondary spectrum was measured. The star 29 Canis Majoris has the largest range of any binary yet discovered, namely, 437 km.

In the course of the regular work during the past few years a number of miscellaneous velocities have been secured. Some of these are of stars, announced as spectroscopic binaries from other observatories, but which proved either of too small a range or otherwise unsuitable for the successful determination of their orbits. For others no velocities had been determined previously. The results for 16 such stars have been published during the past year. The stars are as follows, the numbers indicating the number of plates measured:—

γ Pegasi . .	1	ζ Ophiuchi . .	2
τ Persei . .	2	102 Herculis . .	2
δ Geminorum .	4	Boss 4842 . .	3
β Canis Majoris	14	7 Virginis . .	6
α Cancri . .	48	μ Virginis . .	61
22 Boötis . .	5	Boss 4721 . .	8
α_2 Libræ . .	2	Boss 4826 . .	6
B.D. 55°1793	4	59 Herculis . .	25

Solar Physics.—Though the year was abnormally cloudy and hazy, some 220 plates, comprising over 1200 exposures, each having

from 7 to 9 strips of spectra, were made with the coelostat reflecting telescope and 7 m. auto-collimating spectrograph. Observations were made for investigating the problems of: solar rotation and the effects of haze spectrum; change in character and wave-length of spectrum lines in passing from centre to limb; comparison of solar and arc spectrum lines; and solar distance and periodic variation in wave-length of solar spectrum lines. These problems are investigated simultaneously with the apparatus (now substantially mounted) which has been gradually developed since the mounting of the notched prisms and iodine tube in 1913. It is possible to make simultaneous photographs of the spectra of centre, limbs and intermediate points, arcs and iodine absorption.

Measurements of the solar rotation from spectra from midway points yield larger values than from limb spectra, a fact which furnishes independent proof of the haze spectrum theory. Also, further measurements support the explanation (advanced previously) by this theory of "a cyclic variation of 0·15 km/sec." found here in a series of measures in 1915. The high values of the solar rotation obtained from H_3 and K_3 are explained by the same theory, these lines being very weak in the centre and therefore in the haze spectrum; at the same time the absence of polar retardation is explained. Measurements seem to support the theory advanced here, that the variations in wave-length and character of spectrum lines in passing from centre to limb are due to radial and tangential convection in the pores of the Sun, the latter convection resembling the penumbral convection in spots.

A new form of spectro-comparator, which employs a half-silvered surface to overlap positive and negative images, has been designed, and its construction commenced. A Hartmann spectro-comparator, adapted to do this, has yielded measurements of solar and stellar spectra which have considerably less error than those by other methods. The Evershed method may be employed readily with the new instrument.

Photometry.—Photographic photometry by the extra-focal method has been continued throughout the year, but unusually bad weather has prevented the completion of any light curves. The programme includes mainly spectroscopic binaries, 20 π Cassiopeiæ, 29 Canis Majoris, and g Ursæ Majoris being added to last year's list. The variability of 12 Lacertæ is fully established, the range being ·12 of a magnitude, but the phase shows a shifting which has not been satisfactorily determined. Considerable time has been lost this year owing to the necessity of discarding many plates which were rendered useless by a brown stain, quite heavy around the edges and gradually fading towards the centre. The presence of nitric acid in the fixing bath removed this stain, but first-class plates were not obtained until a new emulsion was used.

Geophysics.—This branch of the activities of the Observatory comprises seismology, terrestrial magnetism and gravity. The equipment of the three divisions consists of the same instruments as reported in the preceding year.

Twenty-five bulletins of earthquakes recorded at the Observatory were issued and sent to other seismological stations during the calendar year 1917, representing 89 seismic disturbances, while during 1916 there were 104, showing a decrease of 15. The world catastrophe has militated against receiving many records for the more accurate plotting and determination of epicentres. The continued study of microseisms is maintained by correlation with the records of the undagraph installed on the Atlantic coast near Halifax, Nova Scotia.

The magnetic survey of Canada undertaken by the Observatory was held in abeyance during 1917, but will be resumed in the coming year, when, as usual, the three elements, declination, inclination, and intensity, will be observed. It is intended to occupy "repeat" stations across the continent for the purpose of reducing the observations of all the stations, some 500, to a uniform epoch.

The gravity survey was also suspended during the year, but it is expected to resume observations during the coming year.

Melbourne Observatory.
(*Dr. J. M. Baldwin, Acting Government Astronomer.*)

Transit-Circle (*8-inch*).—The observations for the year included

	Number of Observations.	
	R.A.	Z.D.
Clock stars	203	138
Azimuth stars	74	55
List stars	242	254
Miscellaneous	16	17
Total	535	464

Collimation has been obtained 39 times; level, 72: nadir, 70: and runs, 13 times.

The small number of observations is accounted for partly by the state of the observing list and partly by the cloudy weather in the latter half of the year, where the great majority of stars remaining in the list occur.

Astrograph.—Owing to the absence of the regular astrographic observer throughout the year, the only plates taken were catalogue plates to replace plates which had been rejected, and plates of Comet Mellish 1917 *a*. The number of plates taken has been

Catalogue	13
Pole	8
Comet	8
Rejected	3
	32

The mounting of the 6-inch doublet was hoisted into position and the parts assembled. The motion of the telescope is very easy, and gives satisfaction. From lack of observers it has not been in regular use.

8-inch Equatorial.—No observations were possible during the year, but the instrument has, as usual, been set apart for visitors on three nights in each lunation.

Reduction of Meridian Observations.—The reduction from apparent to mean place for 1916 is nearly completed.

The General Catalogue of 3068 stars for 1890 has been printed and a large part distributed. Only a few copies have as yet been forwarded to the British Isles or the Continent of Europe. The rest will be sent later.

The manuscript of the General Catalogue of 6089 stars for 1900 has been completed, but it has been decided to compute and insert proper motions for those stars for which positions are available.

Reduction of Astrographic Plates.—The reduction of measured co-ordinates to millimetres, and the application of the réseau corrections, have been completed except for a few recent plates not yet measured.

The measured co-ordinates and diameters have been copied out for the printer to $10^h\ 20^m$, $-68°$.

The intercomparison of overlapping plates remains at $2^h\ 6^m$, $-66°$ with $2^h\ 10^m$, $-67°$, but a number of gaps caused by rejected plates has been filled in.

The identification of C.P.D. stars has been completed to $23^h\ 50^m$, $-67°$.

Magnetic Observations and Reductions.—The absolute value of the Earth's magnetic field has been determined fortnightly throughout the year, and the scale values of the Adie recording instruments at regular intervals. No curves have been measured, but the classification of the curves has been forwarded quarterly to De Bilt.

No money has yet been made available for the erection of the magnetic observatory on an undisturbed site. In the meantime the tramway disturbance is continually increasing in magnitude, and is so serious that probably no use can be made of the vertical force records.

The mean of the observed values of the magnetic elements for 1917 are—

Dec. 8° 3′·2 E H ·22961 I 67° 50′·9

The corresponding values for 1916 were

Dec. 8° 6′·7 E H ·22998 I 67° 48′·9

Seismograph.—In July the seismograph record was stopped for a few days while the instrument was altered. The long ribbon was replaced by a recording drum, and at the same time the speed of

the record was increased from 1 mm. per minute to 3 mm. per minute. The gas formerly used as a light has been replaced by a small electric lamp. This has allowed the ventilation to be very much reduced, so that now the daily range in temperature is very small. The time-signals are now given from one of the standard mean time clocks. The new arrangement has proved much better in every way than the old. The records have been read off, and the results forwarded to Shide Observatory.

The time-service, registration of tides, and various miscellaneous service have been continued as in 1916.

Personal.—No new appointments have been made, and throughout the year Mr. Cornell (astrographic observer) has been absent, at first with the military forces and afterwards on sick leave. Owing to the lack of all temporary assistance the reduction of the magnetic and tidal records has had to be completely discontinued, and the reduction of the astrographic catalogue greatly retarded.

Union Observatory, Johannesburg.
(*Union Astronomer, Mr. R. T. A. Innes.*)

Instrumental Equipment.—This remains unchanged.

9-*inch Refractor* (Mr. Innes).—Measurements of double stars have been continued upon the usual lines, and the eclipses of Jupiter's satellites have been regularly observed. Miscellaneous observations were also made.

$2\frac{5}{8}$-*inch Talcott Telescope* (Mr. Worssell).—This has been used for the time-service.

Franklin-Adams Star Camera (Mr. Wood).—A few photographic observations of minor planets have been obtained during the year, and selected regions of the sky have been photographed for purposes of reproduction.

Twin-Telescope (Mr. Worssell).—Photographs of comet 1917 *a* (Mellish) and a few others were taken. A selected list of variable stars has been under observation.

Blink Microscope.—Work with this instrument has been almost continuous. The Greenwich Zone of $+66°$ has now been searched, with the exception of a few regions for which no pairs of plates are available. The Sydney Zone of $-53°$ has been done, and considerable progress made with Zone $-55°$. A fine series of plates from the Cape Zone $-45°$ has been blinked. By kind permission of H. M. Astronomer at the Cape, Mr. Wood spent the month of October there selecting early chart plates and taking repeat plates; in all he brought back 93 pairs of plates, which are now being blinked. A large number of proper motions have already been found. Amongst those that have been reduced to the arc of a great circle are the following stars:—

1875.

C.P.D.	Mag.	R.A. h	R.A. m	Dec. °	Dec. ′	Centennial Proper Motion ″		°
Anon.	12·5	6	1·8	−55	19	70	towards	243
4033	9·0	10	54·2	−55	57	50	,,	270
77	9·0	0	16·8	−53	12	57	,,	185
Anon.	10·5	2	46·2	−53	40	53	,,	345
,,	12·5	4	5·9	−53	43	124	,,	63
672	8·2	4	12·7	−53	38	99	,,	69
Anon.	12·0	8	6·8	−52	37	82	,,	316
3156	9·1	10	12·4	−51	52	64	,,	90
5750	9·2	12	57·8	−51	45	116	,,	224
9317	9·6	16	2·2	−52	35	55	,,	200
9929	9·6	20	33·1	−53	7	108	,,	180
1588	9·8	7	30·5	−45	1	55	,,	322
3978	9·9	9	39·8	−45	11	72	,,	224
9704	9·2	19	14·7	−45	18	81	,,	185

Time-Service, Meteorological and Seismological Observations.—These have been continued, but in November a slight reduction in the meteorological observations was made; the readings of the Earth-thermometers, for which there are now thirteen years' complete records, have been discontinued, and one of the several rain-gauges put out of commission.

Staff.—Mr. H. E. Wood returned from voluntary military service in German East Africa in February, and has suffered at times from malaria. Mr. E. L. Johnson also returned in January, but almost immediately afterwards volunteered for the Royal Flying Corps, and left in April. He is now on military service in Europe. The work of the Observatory has been necessarily restricted.

Observatory Circulars.—Nos. 36 to 40 were issued during the year, and No. 41 is in the hands of the Government printer. The chief contents of the circulars issued are as follows:—No. 40, variation of latitude 1910–1914, and observations of the R Corona Australis region; No. 37, measures of Southern double stars, Melbourne and Cape proper motion stars found with the blink microscope, and a list of about 170 variable stars, with their range of magnitude and periods (as far as possible), found near Corona Australe by the blink method; No. 38 contains the first of the projected series of maps of the Southern sky, a second map was issued with Circular No. 38, and others are in the hands of the Government printer; No. 39 contains 38 sets of measures of place for Eros (433) extending over a fortnight, and the blink proper motions for 39 pairs of Cape plates along Zone −45°; No. 40 contains the results of the work on *Proxima Centauri*, namely, its parallax = 0″·784 and its centennial proper motion = 385″·2 towards

282°·9, and place observations of the bright comet 1917 *a* (Mellish).

Miscellaneous.—Desk work has included work on the literal and numerical development of the perturbing functions required in Hansen's theory of Jupiter and Saturn, and some progress has been made in preparing eclipse-tables for Jupiter's Satellites I. and II., but the latter work has been delayed by Professor de Sitter's illness and the slowness of communication with Holland.

1918 *January* 8.

Lovedale, South Africa, Private Observatory.
(*Dr. Alex. W. Roberts.*)

The work during the year has been the observation of variable stars with a view to the better determination of secular or other change in the period of those Southern stars that give distinct evidence of such variation.

The detailed observations are:—

Long-period stars . . .	103
Short-period stars . . .	896
Algol stars	366
	1365

Besides this work, progress has been made in the photometric survey of Southern bright stars with the mirror photometer.

The Harvard meridian photometer was also used to determine the absolute brightness of certain comparison stars.

The latter part of the year was very cloudy, and observations were very much interrupted in consequence.

Notes on some Points connected with the Recent Progress of Astronomy.

Discovery of Minor Planets in 1917.

Fifty-four minor planets were discovered or first announced in 1917, as follows:—

Letter and Number.	Date.	Discoverer.
	1916.	
– 850	Mar. 27	B
– 851	Apr. 2	,,
– 852	2	,,
– 853	2	,,
– 854	3	,,
– 856	3	,,
– 857	6	,,
BA	10	Pe
	1917.	
BB	Jan. 21	W
BC	22	,,
BD 860	22	,,
BE 861	22	,,
BF 862	28	,,
BG	28	,,
BH 863	Feb. 9	,,
BJ	13	,,
BK 864	13	,,
BL	13	,,
BN	Feb. 14	W
BO 865	15	,,
BP	23	,,
BQ 866	25	,,
BR	25	,,
BS 867	25	P
BT		
BU 868	Apr. 26	W
BV 869	May 9	Sch, W
BW	12	W
BX 870	12	,,
BY 871	14	,,
BZ 872	21	,,
CA 873	21	,,
CC 874	25	,,
CE	22	,,
CF 875	19	,,
CG	June 15	,,
CH 876	June 20	P
CJ	July 22	W
CK	22	W
CL	22	,,
CM	Aug. 18	,,
CN	July 16	CS
CO	Aug. 26	P
CP	Sept. 14	W, Sch
CQ	22	W
CR	22	,,
CT	23	,,
CU	24	,,
CV	24	,,
CW	25	,,
CX	26	,,
CY	Oct. 21	,,
CZ	Dec. 5	,,
DA	10	,,

The initials stand for:—

B = Mr. Beljawsky, Simeis Observatory, Crimea.
CS = Mr. Comas Sola, Barcelona.
P = Professor Palisa, Vienna.
Pe = Mr. G. H. Peters, Washington.
Sch = Dr. Schorr, Bergedorf Observatory, Hamburg.
W = Professor M. Wolf, Königstuhl Observatory, Heidelberg.

The following planets, unnumbered at the date of the last Report, have received permanent numbers.

827	= 1916 ZW	840	= 1916 AK
828	ZX = 1905 RS	841	AL
829	ZY = 1914 UH = anon. 1906 Feb. 22	842	AM
830	ZZ	843	AN
831	AA	844	AP
832	AB = 1902 KT	845	AS
833	AC	846	AT = 1912 OA
834	AD = 1905 RV	847	AW = 1915 XX
835	AE	848	= 1915 XS
836	AF	849	= 1912 NY
837	AG	855	= 1916 ZP
838	AH	858	= 1916 *a* = 1911 LY
839	AJ	859	= 1916 *b*

The following identities have been established: 856 = 1908 CH, 858 = 1911 LY, 860 = 1903 LE, 861 = 1906 ST, 862 = 1903 LD, 1917 BM = 413 Edburga, 1917 CB = 798, 1917 CS = 775, 1917 CD proved to be a star; 394 Arduina = 1906 UF = 1912 PJ; its orbit has been reinvestigated by B. Asplind (*Ast. Nach.*, 4894, also see 4899), and it was recovered in 1917.

CP was at first announced as Encke's Comet, but was soon found to be a planet.

The following planets have received names: 730 Athanasia, 734 Benda, 750 Oscar, 760 Massinga, 762 Pulkova, 768 Struveana, 769 Tatiana, 779 Nina, 780 Armenia, 781 Kartvelia, 782 Montefiore, 783 Nora, 787 Moskva, 789 Lena, 791 Ani, 803 Picka, 844 Leontina. All the planets up to No. 700 have now been named, and 43 beyond this point.

The following missing planets were recovered last year: 368 Haidea, 413 Edburga, 430 Hybris.

B. Asplind has investigated the perturbations of 236 Honoria in *Ast. Nach.*, 4908, and M. Viljev those of 2 Pallas in 4911. Ten of the newly numbered planets have values of μ above 1000″; the smallest μ among them is 585″ (No. 833); this planet has also the largest ϕ among them, 18°·4; No. 863 has the largest i among them, 25°·5. Besides the 876 numbered planets, 19 more have elliptical orbits calculated, and 54 more have circular orbits calculated, making a total of 949 orbits: the number of planets that have been observed must now be considerably above 1000.

A. C. D. C.

Discovery of Comets in 1917.

1917 *a*. The first cometary discovery of the year was made by Mr. J. E. Mellish at Leetonia, U.S.A., on March 19. It was then of the 8th magnitude and brightened rapidly, so that on April 4 it reached magnitude 2·2, and was independently discovered with the naked eye by Mr. Adolf Paetz. On passing to the south of the Sun it was a very fine object in the morning sky for southern observers, with a curved tail 20° in length; it was independently rediscovered at various places in South Africa, Australia, and New Zealand. Its perihelion distance was small (0·19), which accounts for its rapid rise in brilliance. It is probably periodic, with a period in the neighbourhood of two centuries, but cannot be identified with any comet in our catalogues. It was observed till the end of May.

1917 *b* was discovered by M. A. Schaumasse at Nice on April 25. It was described by M. Guillaume as a circular nebulosity, of yellowish tint, with a central condensation. It was well placed for observation during May, being in high north declination. Owing to its retrograde orbit and a fairly close approach to the Earth (about 0·3), its motion was very rapid. Its magnitude is given by Holetschek as 8·5 on May 12, 8·0 on May 18, 7·3 on May 19. Mr. W. H. Steavenson considered that it just reached naked-eye visibility. Mr. F. E. Seagrave has noted that its orbit and that of the Earth approach each other closely at the point occupied by the Earth on March 30. It was observed till the end of June.

Wolf's Comet (*b* 1916), discovered in April 1916, did not reach perihelion till mid-June 1917. It was under observation for almost the whole year, but never became brighter than the 8th magnitude. Its light was sometimes noted as bluish, and there was evidence of occasional variability of brightness. A short tail was seen on several occasions. On June 15 it was noted by Mr. W. H. Steavenson as being broad and fan-shaped, 5′ in length, in P.A. 250°. Professor Slipher obtained photographs of the spectrum in August at Flagstaff; it was chiefly continuous, but showed faintly the cyanogen band at λ 3883, and a trace of the carbon one at λ 4737. The spectrum was too narrow and faint to show the solar lines, but it was concluded that the comet's light was chiefly reflected sunlight. Mr. F. E. Seagrave has noted that it made a fairly close approach to Vesta in 1917 November.

1917 *c* (Encke) was discovered by Dr. Schorr at Bergedorf on December 30; it was of the 15th magnitude, and agreed within about 1′ with Viljev's ephemeris. Minor planet CP, discovered in September, was at first announced as Encke's Comet, but its divergent motion soon disproved the identity. M. Viljev has shown that the object observed in September 1916, and announced as Encke's Comet near aphelion, cannot really have been that comet, but was either an unknown comet or a faint minor planet.

The following are the orbits of the above four comets; all are for ecliptic and equinox of 1917·0 :—

Comet.	Mellish.	Schaumasse.	Wolf.	Encke.
Computer.	Merfield.	MM. Braae and Fischer-Petersen.	R. J. Crawford and D. Alter.	M. Viljev.
T in G. M. T.	1917 Apr. 10·6883	1917 May 18·2081	1917 June 16·5373	1918 Mar. 24·313
ω	121° 21′ 48″	119° 9′ 35″	120° 36′ 1″	184° 39′ 47″
Ω	87° 23′ 10″	9° 40′ 53″	183° 17′ 50″	334° 34′ 50″
i	32° 37′ 57″	158° 43′ 42″	25° 40′ 11″	12° 31′ 50″
ϕ	83° 50′ 39″	90° 0′ 0″	90° 0′ 0″	57° 48′ 53″
μ	18″·55	0″	0″	1074″·025
log q	9·278620	9·88318	0·227067	9·532582
log a	1·517749	∞	∞	0·345995

D'Arrest's Comet must have passed perihelion about 1917 April, but it escaped undetected.

The following definitive orbits have been published; the short period of 1827 II. is now announced for the first time :—

Comet.	1827 II.	1914 *c* Neujmin.	1915 *a* Mellish.
Computer.	S. Ogura.	J. Svärdsen.	L. Rosenbaum.
T in G. M. T.	1827 June 7·1924	1914 July 30·1206	1915 July 17·1515
ω	19° 18′ 56″	14° 2′ 12″	247° 46′ 6″
Ω	317° 39′ 40″	270° 18′ 27″	72° 16′ 24″
i	136° 26′ 11″	71° 2′ 18″	54° 27′ 22″
log q	9·906709	0·573699	0·0023121
e	0·949491	1·003672	1·000235
Period	63^{y}·83	...	...
Equinox	1827·0	1914·0	1915·0

Neujmin's Comet has the second greatest perihelion distance, the greatest being that of the comet of 1729, whose elements show some resemblance to those of Neujmin's Comet.

Mr. S. Ogura also publishes orbits of two medieval comets, of the years 1132 and 1240, from positions which he has found in the records of Japan (*Annals of Tokyo Observatory*, 5, part 3).

A. C. D. C.

The Eighth and Ninth Satellites of Jupiter.

A photograph of the eighth satellite was secured in December with the 30-inch reflector at Greenwich. The position deviated 20′ from an ephemeris computed by Mr. J. Jackson and published in the *Observatory* for October. The elements used have not been corrected from the observations since the opposition of 1909, so there has been time for a considerable error to accumulate.

Mr. Seth B. Nicholson the discoverer of the ninth satellite, gives a diagram and description of its orbit in *Proceedings of the National Academy of Sciences, Washington*, 3, 147. Its motion is retrograde, and the values of i and Ω in 1915 referred to the ecliptic were 156° and 310°.

The satellite was in apojove early in 1915 at distance 0·190, longitude 99°, and at the end of 1916 at distance 0·215, longitude 127°. The intermediate perijove occurred about the end of 1915 at distance 0·122, longitude 304°. The eccentricity deduced from these figures is 0·248. The sidereal period is about 745 days, 6 days longer than that found for VIII. VIII. and IX. therefore constitute a linked pair with closely similar orbits, VI. and VII. forming another pair. In the case of each pair the perijoves of the two satellites are separated from each other by about 180°, but it cannot be asserted with confidence without investigation that this arrangement is other than accidental.

The magnitude of IX. was found by Mr. Shapley to be 18·3 in 1916 October, corresponding to 18·6 at mean opposition. Making the most probable assumptions of albedo and colour-index, he deduces a diameter of 15 miles. The magnitude of the satellite when full, as seen from Jupiter, would be between the 11th and the 12th.

Mr. Shapley secured a photograph of IX. with the 60-inch reflector at Mount Wilson on 1917 November 10. The corrections to Mr. Nicholson's ephemeris (*Pub. Ast. Soc. Pac.*, 29, 261) were +0′·4 in R.A., −0′·1 in Dec., which are satisfactorily small.

A. C. D. C.

Solar Activity in 1917.

Sun-spots.—The display of sun-spots in 1917 showed a marked increase upon that of 1916, in numbers of individual spots and of distinct groups, in their total and average extent, and in the appearance of groups of abnormal size or character. Thus the great groups of February 4–15 and August 4–16 were among the five largest photographed in the forty-four years of the Greenwich record, and the week August 7 to August 13 yielded day by day a higher daily total spotted area than any previous week in that period. Apart from these two giant groups, long "processions" of spot-groups—groups, that is to say, following each other at short intervals along a parallel of solar latitude—were quite a feature of the year, especially in January, May, and December; while there were several instances of great groups of a very different type, a broad and extended area being sown with small, half-developed spots without any orderly arrangement. May 4 and December 14 showed two striking examples of the kind. Relatively speaking, the form usually expected in an ordinary spot-group—two large spots some 8° or 10° apart on the same parallel of latitude, with a chain of spotlets connecting the two—was not much in evidence. But "regular" spots—circular

or oval in outline, almost geometrical in form, and with dark and sharply defined central umbra—were numerous and unusually large.

The year opened with a fine procession, in the northern hemisphere of the Sun's disc, that had been inherited from the last days of 1916 December. After this had passed off at the west limb, the rest of January remained uneventful. But early in February a superb stream appeared in the southern hemisphere, the first of the two giant groups of the year. A period of many minor disturbances followed, and lasted until April 5, when a quiet week intervened. From April 12 onward the solar activity increased again, until its second culmination in the giant group of August 4–16. September and October witnessed another decline, which lasted until near the end of November, after which a new revival set in, lasting until the end of the year.

The gradual shift of the zones of most disturbance towards the equator during 1917, and the growth of southern towards an equality with northern activity, appear to indicate that the present sun-spot cycle is near the crest of its curve, but probably has not yet reached it. E. W. M.

The Prominences.—The mean daily areas of prominences in square minutes of arc, derived from the Kodaikánal photographic records, are as follows:—

	North.	South.	Total.
1917 January to June . . .	2·94	2·42	5·36
July to December . . .	2·83	2·12	4·95

These figures indicate a considerable increase of activity compared with the previous year, and show that the reduction in 1916 was of a temporary character. The mean daily number of prominences recorded during the year was 19·8.

The distribution in latitude indicates a close approach to the climax of prominence development, when the high latitude zones of activity reach the polar regions. The northern zone is shown to have a maximum between 75° and 80°, and the southern between 70° and 75°. The north is thus slightly ahead of the south in the approach towards the pole. The northern hemisphere has continued to be more active than the southern, and this applies also to prominences projected on the disc as absorption markings, to metallic prominences, and to displacements of the hydrogen lines indicating violent motion.

A great increase in the number and area of the Hα markings has occurred, showing that the prominences generally, from the equator up to latitude 90° north and 50° south, were denser than in 1916. The polar prominences, on the other hand, were comparatively feeble in absorbing power, and only very faint markings are visible in the high latitude zones of activity.

The prominence areas east and west of the Sun's axis show a slight western excess, the proportion on the east side being 49·8

per cent. of the whole. The denser prominences showing as absorption markings on the disc indicate on the other hand the usual eastern excess, the areas east of the meridian being 52·8 per cent. of the whole, derived from 4724 markings. D_3 darkenings and bright reversals of the hydrogen lines on the disc were also slightly more frequent east of the meridian; but of 51 metallic prominences observed at the limb, only 19 were east. 375 displacements of Hα were recorded in the chromosphere and prominences, and of these 52·5 per cent. were on the east limb.

The usual preponderance of displacements of the hydrogen lines towards red is shown, both in prominences at the limb and near spots on the disc.

There were no large eruptive prominences recorded at Kodaikánal during the year. J. E.

Solar Research in 1917.

Periodicity of Sun-spots.—The curve of sun-spot frequency has been further discussed by Sir J. Larmor and N. Yamaga (*Roy. Soc. Proc.*, A, **93**, 493). The chief result is to establish firmly a secular unbroken solar periodicity of about $11\frac{1}{8}$ years, providing it be permissible to reject the two strongly discrepant cycles from 1776 to 1798. The graph of this periodic constituent is anti-symmetrical with respect to the axis which bisects its undulations, each undulation giving equal areas above and below, and the curve repeating as an inverted image; this, it is suggested, may contain a clue for a physical theory. When the periodic part is removed, the residue of the sun-spot activity is of a fortuitous sporadic character, not amenable to further analysis as a whole. In particular, there is no indication of a permanent period of about 8·36 years, such as was suggested by Schuster's analysis of the sun-spot curve, which included the two abnormal cycles.

Solar Rotation.—From a discussion of observations of 58 spots made during 1903–1910, T. Epstein has found the value 73° 59′·2 for the longitude of the ascending node of the sun's equator, and 82° 43′·7 for the inclination of the sun's axis to the ecliptic (*Ast. Nach.*, 4892). The equinox is that of 1901·0. These do not differ materially from the Carrington values which have hitherto been generally adopted.

From a study of the centres of sun-spot activity during three complete periods, based upon the Stonyhurst drawings for the first two, and upon the Greenwich results for the third period, Dr Henroteau (*Mem. Soc. Spett. Ital.*, **5**, series 2) concludes that there is an inequality in the rotation periods of the two solar hemispheres.

The possible effects of atmospheric haze upon the apparent rate of solar rotation, as determined by the spectrographic method, have been further discussed by R. E. de Lury (*Jour. R. A. S. Canada*, **11**, 23), C. G. Abbot (*Ap. J.*, **45**, 65), and H. H. Plaskett (*Ap. J.*, **45**, 144). Mr. Plaskett finds no evidence in the observa-

tional data in favour of de Lury's suggestion that apparent changes in the rate of solar rotation might be due to variations in the amount of scattered light. From his bolometric observations Abbot also concludes that an effect due to haze on good observing days would be very small.

Solar Prominences. — From an extensive investigation of spectroheliograms taken at the Yerkes Observatory it has been shown by O. J. Lee that only a small percentage of prominences are associated with sun-spots or flocculi (*Ap. J.*, **45**, 206). Many large eruptive prominences occurred either where there was no apparent surface disturbance, or where the surface was merely roughened. Very bright flocculi were usually represented at the limb by jets, and only rarely by prominences of any considerable size. On the other hand, 81 per cent. of the 78 "filaments" which could be traced to the limb terminated in prominences, indicating a close connection between these phenomena. The identity of the dark filaments with prominences has also been confirmed by the Mount Wilson observations (*Mount Wilson Report*, 1916).

Details of the great prominence of 1916 May 26 have been given by Evershed (*Kod. Obs. Bull.*, No. 55). Numerous spectroheliograms were obtained at short intervals, and several fine examples are reproduced. The highest point reached by the prominence was half a million miles above the sun's surface.

A valuable memoir on solar prominences has been prepared by Mr. and Mrs. Evershed (*Kod. Obs. Mem.*, **1**, part 2). It includes the chief results of a discussion of visual and spectroheliographic observations made at Kenley and Kodaikánal from 1890 to 1914 (see President's Address).

Under the title of "Solar Hydrogen Bombs," F. Ellerman describes an interesting solar phenomenon which has been studied at Mount Wilson by photographic and visual methods (*Ap. J.*, **46**, 298). Among the components of active spot-groups, and in faculæ, these bombs exhibit themselves as brilliant narrow bands extending on both sides of the hydrogen lines for several angstroms. They are of very short duration, and sometimes occur in succession at intervals varying from ten to twenty minutes. The hydrogen absorption lines are not affected, thus distinguishing the bombs from the ordinary eruptive reversals. A large image and good seeing are essential conditions for observations of the bombs.

Solar Vortices.—Further results relating to solar vortices have been included by Hale in his report on the work of the Mount Wilson Observatory for 1916. It appears that while there was a reversal of the magnetic polarities of the spot-fields after the last sun-spot minimum, there was no change in the direction of whirl in the overlying hydrogen vortices. This is regarded as a serious objection to the hypothesis that the configuration of a hydrogen vortex is caused by the magnetic field of the underlying spot, and in view of experimental evidence on vortex motion it seems more probable that the structure is of hydrodynamic origin.

Displacements of Solar Lines.—The displacements of lines of nickel and titanium at the centre and limb of the sun have been studied by Royds with the aid of direct comparisons of solar and arc spectra (*Kod. Obs. Bull.*, No. 51). Some difficulty was caused by the unsymmetrical character of many of the lines of the elements in question, but the results are considered to be consistent with those deduced from lines of iron; namely, that the pressure in the reversing layer is less than one atmosphere, and that there is a descending motion of the vapours at the centre of the disc.

As a partial outcome of studies of the iron arc for the elimination of "pole effect," and the establishment of a convenient source of standard wave-lengths, St. John and Babcock have found that certain peculiar displacements of solar iron lines cease to be abnormal when the fundamental wave-lengths of such lines are used as the terms of comparison (*Ap. J.*, **46**, 138).

Dr. St. John has sought for evidence of the displacement of lines in the solar spectrum which is predicted by Einstein's equivalence principle of generalised relativity as an effect of the sun's gravitational field (*Proc. N.A. Wash.*, 3, 450, and *Ap. J.*, **46**, 249). Lines forming part of the cyanogen band λ 3883, which are free from pressure shifts, were measured at the centre and limb of the sun, but no evidence of an effect of the required order was obtained. Two other series of observations at Mount Wilson are also at variance with the relativity principle; namely, the equal wave-lengths of the H and K lines of calcium in the arc and at the sun's limb, and a centre-arc displacement of 0·004 A at λ 6300 for iron lines in place of 0·013 A required by the relativity principle.

Solar Radiation.—An investigation of the ultra-violet radiation of the sun has been made by Birkeland, by the use of a light-filter consisting of a silver film which was opaque to visible light, the transmitted energy being measured by a photo-electric cell (*Cairo Sci. Jour.*, 8, 287). While the variations observed were to be attributed in part to changes in atmospheric conditions, changes in the electrical state of the sun were regarded as another possible cause.

An attempt to correlate meteorological phenomena with the short-period changes in solar radiation, indicated by the work of Abbot, has been made by H. Helm Clayton (*Smithson. Misc. Collec.*, **68**, No. 3). Among other results, there were indications of a periodicity of about twenty-two days in the solar variations, and a similar period was shown by the temperature records at Buenos Ayres.

Abbé Th. Moreux has compared the numbers of icebergs in the Atlantic with the sun-spot numbers for the years 1888 to 1915 (*Rev. du Ciel*, 2, 139). The two curves for this period are closely similar, the minimum number of icebergs occurring at a maximum of spots.

Miscellaneous.—An interesting summary of our knowledge of sun-spots has been given by Father Cortie in *Science Progress* for 1917 October. An attempt is made to connect the various

phenomena on the supposition that a spot is caused by an uprush of vapours which are lowered in temperature by expansion.

In a note on the uprush of gases in solar prominences (*Observatory*, **40**, 97), A. A. Buss discusses the observational evidence in favour of his view that beneath the visible photosphere there is a constricting shell which encloses matter in a quasi-liquid state, and that the eruptive prominences represent localised escapes of the intra-solar matter.

The supposed "abnormal" solar spectra described by Hale in 1902 have been satisfactorily explained by F. E. Baxandall as having been caused by the accidental superposition of spectra of different orders (*Ap. J.*, **46**, 291). A. F.

Double Stars.

Definition of the Term Double Star.—In a paper published in the *Monthly Register of the Society for Practical Astronomy*, vol. ix., No. 2, F. C. Leonard points out again the real advantage of Professor R. G. Aitken's definition of the term double star. Some astronomers have objected to the definition, and the author endeavours to show that these objections are not well founded. It is evident that a limit must be set somewhere. Various double-star observers have at different times adopted for themselves diverse limits of separation; Struve's limit was 32″, Otto Struve 16″, Espin 10″, Aitken, Hussey, and Jonckheere 5″. The result is, as R. G. Aitken has aptly remarked, "that a complete catalogue, like Burnham's General Catalogue, contains a most heterogeneous collection of objects."

It was in 1911 that Aitken published (*Ast. Nach.*, 4505) quotations of letters he received from numerous astronomers in answer to his suggestion of limiting the term double stars to pairs within certain separations. These limits were for the telescopic stars:

1″	for combined magnitude of	or fainter than	11·1.
3″	,,	,, or brighter than	11·0.
5″	,,	,, ,,	9·0.

Aitken, Barnard, Bigourdan, Burnham, Doberck, Espin, Fox, Innes, Jonckheere, Lau, Lohse, Pickering, See, Storey, van Biesbroeck were in favour of a limit, and nearly all agreed to a maximum separation of 5″ for a 9·0 (B.D.) magnitude star.

Several astronomers were of the opinion that the limits given by Aitken for stars fainter than 9·0 should be slightly increased. P. Fox wrote that he would not like to exclude any pair whose distance is less than 5″. E. E. Barnard wished to increase the limiting distances for the smaller stars because of the probable proximity to us of many of the faint stars. R. Jonckheere suggested a gradual scale rather than the broken line or series of steps of Aitken's table. Halving the separation for each drop of two

magnitudes, and taking the limit of 5″ for a 9th magnitude, as already generally adopted at the time by Aitken, Hussey, and himself, he gave a table of the following form:

2″·5	for a star	magnitude	11·0
3·7	,,	,,	10·0
5·0	,,	,,	9·0
7·5	,,	,,	8·0
10·0	,,	,,	7·0

Now that a few years have passed, it has become clearer that Professor Aitken's appeal was really most successful. The debated points were of minor importance compared to the chief limit of 5″ for a 9·0 B.D. agreed upon by the great majority of astronomers. W. J. Hussey was the only double-star discoverer who rejected the proposal, but here again the disagreement was more apparent than real, for he had himself wisely adopted the 5″ limit for his double-star survey at the Lick Observatory.

Double Star Distribution.—R. Jonckheere has published a new catalogue of the double stars discovered visually from 1905 to 1916, but excluding all pairs exceeding a separation of 5″ (*Mem. R.A.S.*, 61). There are 3950 entries, representing two-fifths of all the double stars known to that limit.

The volume contains a study of the distribution of double stars. It appears that the ratio of the number of close double stars to that of single stars depends on the star density in a given region. The greater the number of stars, the greater the ratio of double to single stars, and this without any regard to the galactic latitude of the region. The conclusion is not quite in agreement with that of Professor Aitken. From an investigation of the ratios of the number of double stars of different separation limits, this distribution does not appear to be produced by a greater number of optical pairs under 5″ in the denser regions, and its cause is therefore not so obvious as might at first appear.

New Pairs.—During the year 1917, the number of new double stars announced was 329. T. E. Espin, continuing his double-star survey with a 24-inch reflector, has contributed 62 new pairs under 5″ and a number of wider stars (*M.N.*, 77, 239). F. Leonard has one new close pair found with the 6½-inch refractor of the Student's Observatory of the University of Chicago (*Pop. Ast.*, 25, 340). E. Pettit, with the 11½ equatorial of the Washburn College Observatory, found, as a result of a three-months' survey, 9 double stars under 5″ (*A.J.*, 715). E. D. Roe, jr., gives 5 new pairs under the same limit in *Ast. Nach.*, 4874; and R. Jonckheere published 252 new close double stars discovered with the 28-inch refractor of the Royal Observatory, Greenwich (*Mem. R.A.S.*, 61).

Measures.—A great many measures have been published, chiefly in the *Astronomical Journal*. F. P. Leavenworth, in No. 708–709, has two series of 80 stars measured with the 40-inch and 12-inch refractors of the Yerkes Observatory. Leavenworth

finds that 0″·35 may be taken to represent the average condition of the nights for the whole series with the 40-inch. We learn that the 40-inch is provided with an Iris diaphragm, and that apertures of 18 or 24 in. were sometimes used.

In No. 714, C. P. Olivier gives measures of 100 stars made with the 26-inch refractor of the Leander M'Cormick Observatory. These observations are specially valuable, for they are mostly of stars discovered since 1900 and as yet uninvestigated. At the end of the paper a list is given of the residuals Olivier-Jonckheere, and it appears that there is a very large systematic difference in the measured distances of the two observers. Comparisons with other double-star discoverers are not given.

No. 715 contains measures of 138 double stars made by E. Pettit with the 11½-inch refractor of the Washburn College Observatory, Topeka, Kansas. Each pair was observed on three nights. The list includes a few modern pairs and several new ones which have already been referred to.

R. Jonckheere, in No. 721, publishes a first list of a series of measures of well-known binaries obtained at the Observatory of the University of Lille and at the Royal Observatory, Greenwich. The stars are observed on numerous nights, and the measures extend over several years. In the second part of the paper the condition of the image is given for the very close pairs, together with the residuals (O–C) computed from the orbits.

In the *Monthly Notices*, **77**, 236, T. E. Espin gives measures of 104 pairs. These observations were made with a 24-inch reflector, and include many Herschel pairs.

T. E. R. Phillips published observations of 37 double stars observed with the 8-inch Coleman telescope of the Society (*M.N.*, **77**, 624). ξ Boötis and 70 Ophiuchi received special attention, the latter being measured on twenty-one nights.

W. S. Franks, with a 6-inch refractor, observed many stars, mostly Struve pairs. There are 267 in *M.N.*, **77**, 46, and 250 in *M.N.*, **78**, 82. These lists show again the very large field of valuable work on double stars which is open to a small telescope.

R. T. A. Innes, in the *Union Observatory Circular*, No. 37, published measures of 98 double stars. Notes indicate the interesting facts revealed by some of these new observations.

Ast. Nach. contains measures of a few pairs by E. D. Roe, jr. (4874); observations, mostly on single nights, of 39 stars by H. E. Lau (4980); and photographic measures of 91 Struve pairs by E. Hertzsprung (4915). These latter were obtained with the 20-inch Potsdam visual objective, and are therefore more trustworthy than the usual photographic double-star measures.

Vol. **61** of the Royal Astronomical Society *Memoirs* contains several thousand new measures, made by R. Jonckheere, partly with the 28-inch refractor of the Royal Observatory, Greenwich.

Sirius and Procyon.—E. E. Barnard, in *A.J.*, 716, C. P. Olivier, in *A.J.*, 704, 714, and R. Jonckheere, in the *Observatory*, **40**, 203,

have published the following observations of the companion of Sirius :—

		°	″	
Olivier .	1915·92	75·1	10·46	26 inch.
Barnard .	1915·99	75·1	10·66	40 ,,
Jonckheere .	1916·07	74·2	10·57	28 ,,
Olivier .	1916·86	74·2	10·61	26 ,,
Barnard .	1916·95	73·8	10·80	40 ,,
Jonckheere .	1917·23	73·9	10·61	28 ,,

In the *Observatory*, **40**, 203, the comparisons O–C are given with the orbits of T. J. J. See and O. Lohse.

With regard to Procyon, this double star has lately been most perplexing. The companion has not been seen at the Lick Observatory since 1906. In 1910, E. E. Barnard obtained only one complete measure of it. In 1911, R. Jonckheere observed it on two nights, and Professor Barnard in 1913 again saw it with difficulty. At Greenwich, doubtful observations of the companion were obtained on three nights in the last four years, but it was impossible to determine whether the faint object observed near the bright primary was not a spurious image, especially as the instrument employed cannot be reversed. These observations of Procyon as a double star are unsatisfactory, because neither Lewis Boss's orbit nor the motion indicated by the early measures will account for the failure to see the companion since 1906 with the instrument with which it was discovered in 1896.

Orbits of Binaries.—G. C. Comstock has made a reinvestigation of the orbit of ζ *Herculis* (*A.J.*, 712). The material used falls between 1826 and 1916, and covers approximately two and a half revolutions. The new elements give a period of $34^{y}\cdot46$, and G. C. Comstock does not support the hypothesis of a gradual increase in the period.

H. N. Russell has a study of the orbit of ϵ Equulei (*A.J.*, 710) and gives new elements with a period of 97 years. An ephemeris shows that the separation will, according to this orbit, remain well under $0''\cdot2$ during the next ten years. The relative motion of the distant companion at $10''\cdot7$ makes it very probable, as has already been pointed out, that it is revolving round the primary system. H. N. Russell finds that, if moving in a circular orbit, the period of this wide system would be 5900 years.

In *A.J.*, 711, H. N. Russell also publishes a very complete investigation of that most interesting system of faint stars, 60 Krueger. The observation curves were first adjusted by the classical methods of Sir John Herschel. From points derived from these curves, the apparent ellipse was drawn on co-ordinate paper and the elements of this ellipse determined analytically. The true orbit was then obtained by Lohse's modification of Zwier's methods. In this case three possible orbits were thus obtained for 60 Krueger with major semi-axis of $2''\cdot49$, $2''\cdot55$ and $2''\cdot86$ respectively. Comparisons (O-C) are given for the three orbits, and ephemerides computed for two.

The well-determined parallax of 0″·256 of the system and the numerous measures by Professor Barnard of the distant optical companion *c* afford good material for the determination of the ratio of the masses of the components. It now seems certain that, contrary to the result of 1910, the fainter star is considerably less massive than the bright component. The total mass of the system is 0·45 times that of the Sun. The fainter component has probably between one-sixth and one-eighth of the mass of the Sun, and this, the author notes, is by far the smallest mass which has so far been assigned to a visible star.

H. N. Russell has recently presented at the twenty-first meeting of the American Astronomical Society (*Pop. Ast.*, **75**, 667) several papers on orbits of visual binaries, together with new formulæ for their determination. Double-star astronomers are looking forward to the publication of this work.

E. Hertzsprung, in *Ast. Nach.*, 4871, gives a new orbit of Σ 1865, ζ Boötis; assuming that all the observations should be placed in the second quadrant, he finds a period of 130 years, with an eccentricity of 0·96. This last value is very large for a double-star system, but is not without a precedent.

S. Opik, in *Ap. J.*, **44**, 292, applies the surface-brightness derived from Wilsing and Scheiner's corrected stellar temperatures to determine the densities of 40 visual binaries with known orbits. This is found to be comparatively high for these binaries, in contrast to the extremely low densities of many spectroscopic binaries.

Astrographic Double Stars. — F. A. Bellamy has, in *M.N.*, **77**, 521, a paper on the systematic errors of photographic distances of double stars. From a comparison of the photographic determinations with the visual measures of 436 pairs, it appears that in the distance there is a systematic difference for the double stars separated by less than 6″. The distances are measured smaller on the plate. The value of the paper is enhanced by a list of the most interesting discrepancies found between the photographic results and the latest visual observations.

R. Jonckheere, in the *Observatory*, **40**, 233, questions whether the photographic double stars should be included in double-star catalogues, and investigates the value of the astrographic double stars. The paper is divided into sections dealing respectively with the class of these double stars, the quality of the measures, the magnitudes, and the reliability of the duplicity. It is shown that the astrographic results are most unsatisfactory on every one of these points. The double-star information derived from the ordinary astrographic rectangular co-ordinates cannot be relied upon, and even with a 28-inch refractor it is quite problematic whether a given close "astrographic double star" can be found in the sky at all.

Following on this paper, R. T. A. Innes, in the *Observatory*, **40**, 410, states that he is in general agreement with R. Jonckheere's conclusions. At Johannesburg, several of the close pairs of the Perth catalogue were looked for visually. Mr. R. T. A. Innes has

had considerable experience in the examination of plates for many years, and his opinion is that it is useless to include in double-star catalogues the small astrographic double stars.

Miscellaneous.—Robert G. Aitken, in the *Pub. Ast. Soc. Pac.*, **28**, 276, indicates some of the large changes found by the re-measurement of the double stars previously discovered by him. This material already affords proof that the Aitken discoveries will include many very interesting binaries, perhaps the most interesting systems contained in any one catalogue.

In the same publication, **29**, 207, Robert G. Aitken publishes measures obtained recently of the star OΣ 341. These new observations show that we have to revise entirely our views as to the character of this system. It now appears probable that the orbit is very eccentric and of a period of only about twenty years. Another note in the same number shows likewise that from recent measures of β 1026 it seems that the period of this binary may be much shorter than previous estimates.

R. Jonckheere, in the *Observatory*, **40**, 122, calls attention to several new double stars for which the measures seem to indicate a possible motion.

F. A. Bellamy (*The Observatory*, **40**, 168) notes that one of the close pairs given by R. Jonckheere in the above paper is in the zone of the Oxford Astrographic Catalogue. This star, J 25, Cambridge 10,553, is recorded on five plates. On the first plate, taken in 1895, the second exposure images are slightly elongated; but in 1900, 1906, 1907 there is no trace of duplicity. No sensible proper motion is found for the combined mass, but these plates establish that, except for a slight elongation in 1895, the components of the double star have remained too close for the separating power of the photographs during the last twenty years.

E. E. Barnard, in *A.J.*, 719, gives observations of the planetary nebula, Jonckheere 900, which he secured in 1913 with the 40-inch of Yerkes. With this instrument the object appears fairly bright, with a bluish-white disc of 7″·9, but the two condensations measured as a double star at Lille in 1912 could not be seen at Yerkes. As usual, Professor Barnard determined rigorously the co-ordinates of the object and measured the nearest star.

R. Jonckheere, commenting on this paper (*The Observatory*, **40**, 459), remarks that when he discovered this object it was showing two small nuclei, but that in 1915 he had noted himself that it appeared with three doubtful condensations. Real change is possible in the appearance of points of light in the nebula. There is also an interesting change in the measures connecting the object with the nearest star, but this again may be due to changes in the location of different bright patches in the tiny nebula.

The *Publications of the Astronomical Society of the Pacific*, **29**, contains papers by H. D. Curtis, W. W. Campbell, and J. H. Moore, which include observations of another planetary nebula (Jonckheere 320) first noted and catalogued as a double star. A drawing of the object is given. The spectrographic

observations made at the Lick Observatory indicate that this nebula is rotating about an axis coinciding approximately with the shorter axis of the bright central oval, in the sense that a point on the major axis of the oval 3″ south-east of the centre, has a velocity of approach of about 10 km/sec relative to that of the corresponding point north-west of the centre. When one considers the very small apparent size and light of this object, these determinations appear very wonderful indeed.

E. Doolittle continues in *M.N.*, **77**, 437 and 626, and in *Pubs. Ast. Soc. Pac.*, **29**, 60, his lists of errata to double-star papers. He deals with those published in *M.N.*, **66** to **75**, the Espin list in *M.N.*, **77**, and the list in *Lick Obs. Pub.*, **12**. The corrections given by E. Doolittle are those which appear probable so far as one may judge without reference to the original observations.

W. S. Franks, in *M.N.*, **77**, 54, gives an investigation of Sir W. Herschel's double-star measures. It is well known that W. Herschel's distances are almost invariably too small. Franks has made a comparison between Herschel and Struve, taking all measured objects common to both. On the whole, Herschel distances require a plus correction amounting to 5 to 8½ per cent. from Class IV. outwards. The distances in these classes being very great, the actual defect is large.

The *Companion to the Observatory*, 1918, contains recent measures of well-known binaries and computed ephemerides for forty-one systems. R. J.

The Barnard Proper Motion Star.

Several values of the parallax of this star have been published during the year. Professor Schlesinger finds 0″·52, Dr. Mitchell 0″·47, Mr. Lee 0″·55, Mr. van Maanen 0″·52. After applying +″·002 to reduce to absolute parallax, the mean is 0″·52, implying a distance of 6·27 light years. It is the second nearest known star, reckoning the Innes star and α Centauri as a single system.

The Proper Motion in R.A. is about $-{}^{s}0\cdot47$, that in declination +10″·27, the latter having a secular increase of 0″·10 owing to the diminishing distance. The position for 1915·0 referred to Boss's system is R.A. $17^{h}\ 53^{m}\ 31^{s}\cdot428$, N. Dec. 4° 27′ 33″·25. The star occurs in the recently published volume of the *Toulouse Astrographic Catalogue* on Plate 135, taken 1898 July 8; the centre of the plate is at R.A. $17^{h}\ 56^{m}$, Dec. +5°.

The following are the rectangular co-ordinates of the star and a few of its neighbours as given in the Catalogue :—

Number.	Star.	Mag.	X.	Y.
336	Barnard Star	11·0	−45′·4245	−33′·8200*
330	B.D. +4° 3560	8·9	−47′·8912	−31′·5878
337	Munich (2) 6966	10·5	−44′·8176	−43′·2593
334	*n*	12·8	−45′·6833	−33′·7431

* Printed 23′ in Catalogue, but this is an obvious misprint. The notation *n* is given by Professor Barnard in *A. J.*, 695.

Messrs. Walter S. Adams and A. H. Joy (*Ap. J.*, **46**, 313) take the visual magnitude as 9·7, corresponding to absolute visual magnitude 13·3, and luminosity 0·0005 of the Sun; spectral type Mb. The determination of its parallax has enabled them to extend their reduction curves connecting spectral character with absolute luminosity from abs. mag. 11·0 to 13·3. They find that the strontium line at λ 4607 is very sensitive to changes of absolute magnitude, and more suitable for use in these dwarf M stars than the calcium line at λ 4455 previously employed. A. C. D. C.

The Innes Proper Motion Star.

Mr. R. T. A. Innes gives in Circular 40 of the Union Observatory some details of the proper motion and parallax of this star, for which the name Proxima Centauri has been proposed. The proper motion has been accurately deduced with the aid of three Sydney Astrographic plates of dates 1896·3, 1901·4, 1909·5, which are combined with the recent measures 1917·0. A proper motion of 3″·852 towards 282°·9 represents all of these with no residual exceeding 0″·4, so that it is probably correct to 1 part in 200.

The value for α Centauri is 3″·68 towards 281°·4. If the motion of Proxima were parallel to that of α it would be towards 283°·6, owing to the different R.A. and Declination of the stars, which are 2° 11′ apart. Hence the discordance from parallelism is only 0°·7, a quantity so small as to render the assumption quite reasonable that the linear motions of α and Proxima are sensibly equal and parallel. In this case the parallax of Proxima would be 385/368 of that of α, giving the value 0″·796, which is in good accord with that given by the observations; Mr. Innes's measures gave 0″·802, and Mr. Voûte's 0″·755. The latter were deduced using an earlier value of the P.M., and would be somewhat modified on substituting the latest value.

Taking into account the line of sight velocity, which is −22·19 km/sec for the centre of gravity of α^1, α^2 (*Lick Obs. Pubs.*, 9), then if Proxima were at the same distance from us as α, and had equal and parallel linear motion, its apparent proper motion would be 3″·73 in 281°·68. Hence the hypothetical parallax is $0''{\cdot}759 \times 385/373 = 0''{\cdot}784$. On these assumptions Proxima is distant from α Centauri 10,378 astronomical units perpendicular to the line of sight, and 8666 units in the line of sight, making a total distance of 13,522 units. Taking the mass of the system as $2{\cdot}05 \times \odot$, the period in a circular orbit is 1·1 million years, which would give an apparent relative annual motion, if unforeshortened, of 0″·06. From the fact that the observed position angle of Proxima's motion is greater than that calculated, we may perhaps conclude that the direction of orbital motion is counter-clockwise, *i.e.* it is in agreement with the orbital motion of α^1, α^2 Centauri.

Mr. Voûte gives the visual and photographic magnitudes as 11·0 and 13·5, corresponding to absolute magnitudes 15·4 and 17·9 respectively. It is the faintest star known, having less than a ten-thousandth of the luminosity of the Sun. A. C. D. C.

Variable Stars.

Despite the war, the recent output of literature dealing with variable stars has been very considerable, and includes some papers of great importance.

Miscellaneous Papers.—In *M.N.*, **77**, 550, A. N. Brown publishes his observations of RT Cygni in the years 1912–17, and in the same number H. H. Turner and Miss M. A. Blagg give a further instalment of Baxendell's Observations of Variable Stars which they are jointly editing.

The photographic study of short-period variables has been continued by C. Martin and H. C. Plummer at Dunsink, and three papers have been published on SX Aurigæ, B.D. + 56°·547, and RZ Cephei respectively (*M.N.*, **77**, 627, 651; **78**, 185). The light curve of B.D. + 56°·547 with two unequal maxima and minima is of special interest. Its main features are represented by the very simple formula

$$m = 10{\cdot}09 - 0{\cdot}095(\cos\theta + 2\cos 2\theta),$$

where θ corresponds to the principal maximum. The period is as long as 704 days.

The three following papers appear in *Jour. B.A.A.*:—

Report of the Rousdon Observatory, with notes on 13 long-period variables by C. Grover (**27**, 116).

Variable Star Section, Report No. 20.—This paper summarises the observations of SS Cygni in 1916. No less than 10 maxima —an unprecedented number—occurred during the year, and in the last few months there was a marked tendency for the star to remain at a minimum nearly a magnitude brighter than usual (**27**, 145).

Variable Star Section, Report No. 21.—This paper deals with the observation of long-period variables in 1916 (**27**, 226).

Harvard Annals, **80**, 137, contains the results of an exhaustive investigation by H. C. Wilson of the long-period variable T Andromedæ, based partly on 800 plates taken at Harvard between 1889 December and 1916 February, and partly on the visual observations of various observers. The light curve is given with 24 ordinates, the colour index at each ordinate, and the deduced elements. There is an oscillation of the maximum, which seems so far to be fairly well represented by a sine term.

In *Journal des Observateurs*, **2**, 13, M. Luizet gives his determination of the maxima and minima of a number of stars and provisional elements. Four of the stars have periods between 45 and 100 days, and thus fall in the gap between the short- and long-period variables.

In *Ast. Nach.*, 4897, under the title "Remarks on Argelander's Method of Estimating the Brightness of Stars," H. Osthoff discusses the difficulties connected with the colours of variables and methods of dealing with them.

M. Wolf reports that five variable stars in Perseus exhibit a common motion (*Ast. Nach.*, 4898).

In *Ast. Nach.*, 4899, J. G. Hagen compares the magnitudes of the stars surrounding the variables Y Cygni, RV Herculis, and T Herculis in the *A.S.V.* with those assigned to the same stars in the Greenwich and Oxford Zones of the Astrographic Catalogue.

In *Ast. Nach.*, 4921, after a study of the assigned magnitudes of variable stars of all types, A. A. Nijland compares the scales of Pickering (Harvard) and Parkhurst. He finds a considerable discrepancy, which is represented by the formula

$$H - P = 0^{m}\cdot22(H - 9^{m}\cdot33).$$

Numerous observations and discussions relating to variables have been published in *Pop. Ast.*

Variable Star Problems.—An important paper has been published by H. H. Turner on the Classification of Long-period Variables (*M.N.*, **78**, 92). This follows up his previous work (*M.N.*, **64**, 549, **67**, 334; *Mem. R.A.S.*, **55**, xcvii), in the course of which he had been led to put forward the hypothesis that variable stars have their axes of rotation roughly parallel to Galaxy. He now re-examines this hypothesis in the light of the twofold division into which the long-period variables have lately been shown by Phillips to fall (*Jour. B.A.A.*, **27**, 6). He finds that it is still consistent with the evidence as regards one of the divisions, but that it does not fit the other satisfactorily without some rearrangement of the groups. With reference to the analytical expressions for the light curves he suggests a purely geometrical interpretation of the characteristic relations of the phases of the second and third harmonics in the two groups, though the analysis serves to distinguish the one division from the other.

The problem of *Cepheid* variables has been again under discussion. The difficulties attached to the binary interpretation of the light and velocity curves have, perhaps, not been lessened, but, on the other hand, Shapley's pulsation theory, though gaining in favour, is as yet by no means established.

In *Observatory*, **40**, 290, A. S. Eddington has discussed some of the problems connected with this theory. It is a well-known peculiarity of stars of the Cepheid-Geminid type that the maximum brightness occurs at the time of most rapid approach, as indicated by the spectroscope, whereas the minimum takes place at or very near to the point of swiftest recession. Obviously at these times, on the pulsation theory, the star is passing through the state of mean density, in the one case (relatively to the average rate of radiation) losing heat as it becomes more rarefied, in the other gaining it as it contracts. Its pulsations may accordingly be analogous to those of a sound wave, in which a loss or gain of heat at a point

of normal density leaves the energy of the vibrations unaffected. Radiation pressure in the star is also referred to as one of the contributory causes in the maintenance of the pulsations. How the existing state of things could come about in the first instance cannot yet be stated, but it is suggested that if an infinitely small pulsation were started it would probably increase, under causes discussed, up to a limit, and that it is not necessary to call in the aid of a cataclysm in the star's early history, such as Shapley has postulated.

In *Ast. Nach.*, 4903, P. Guthnick, in reviewing results obtained by photo-electric means during 1914–16, remarks that it cannot yet be said positively that stars of the δ Cephei class are not double stars. Indeed it appears that he still holds to the theory of orbital motion in these objects, though he considers it probable that the displacement of the spectral lines does not arise solely from such motion. In one or two cases he separates eclipse effects from what he believes to be the background of the ordinary light curve of a Cepheid or Geminid variable, and attributes the latter variations to axial rotation combined with revolution through an atmosphere of varying density and transparency.

H. Shapley's paper in *Ap. J.*, **44**, 273, may be recalled in this connection, which makes it evident that in a general way the brightness of Cepheid stars is connected with spectral conditions prevailing on their surfaces, although the exact relation is not yet determined.

A further contribution to the Cepheid problem from another point of view is made by C. Martin and H. C. Plummer in their paper on RZ Cephei (*M.N.*, **78**, 156). They point out that this and seven other short-period variables observed at Dunsink show a striking accordance in the phases of their harmonics with a number of long-period variables in Phillips's Group II. (*Jour. B.A.A.*, **27**, 6). They had previously abandoned the binary interpretation of Cepheid variation in favour of Shapley's pulsation theory (*M.N.*, **75**, 573), and they are now led to the suggestion that a similar process manifests itself in variables whatever differences of range or period the circumstances of individual stars may dictate.

The problem of stellar variability (apart from eclipsing systems) has clearly reached a very interesting stage. It shows signs of becoming unified and generalised, and there are grounds for the hope that even the behaviour of those stars now classed as "irregular" may before long prove more readily amenable to analytical treatment.

Eclipsing Variables.—Numerous papers dealing with these objects have been published during 1917 in the *Bulletins of the Laws Observatory*, the *Astrophysical Journal*, the *Astronomische Nachrichten*, and elsewhere.

A paper of special importance will be found in *Ap. J.*, **45**, 200, by H. N. Russell, M. Fowler, and M. C. Boston. It contains the first results of a piece of co-operative work by the Harvard and Princeton Observatories in the measurement and discussion of variable stars in the plates of the Harvard Photographic Library.

Over 2000 photographic observations of six stars have been discussed, and geometrical elements of eclipsing systems derived, which on the whole give a satisfactory representation of both the photographic and visual light curves. But the relative brightness of the components (and in some cases the amount of darkening towards the limb) does not quite agree for the visual and photographic rays, and there is a difference between the time of mid-eclipse, indicated by the two methods, which cannot be attributed to accidental error. In some instances definite evidence is forthcoming that the disc of the brighter component appears redder at the edges than at the centre, as is the case with the Sun. It is also found that components equal in surface brightness are of the same colour, but that where there is a difference the star of lower intensity is the redder. Some of the stars show a difference in the colour index of the components as great as that between the spectral types A and G. When the exact ratio between the difference of colour index and the difference of surface brightness can be fixed, it will be possible to estimate both the linear diameters of all stars of known colour index and parallax, and the angular diameters of all stars of known spectral type.

Novæ.—As Novæ are often classed with variable stars, though probably their light emissions come from a totally different cause, some mention may be made here of observations of these objects reported in 1917. Nova Persei (1901) has been carefully watched, and has been exhibiting some interesting fluctuations (*Ast. Nach.*, 4903 and 4910). Professor Barnard again observed the nebulous wisp seen by him in 1916, and W. H. Steavenson recorded a feeble nebulosity surrounding the star.

The discovery of several Novæ in spiral nebulæ was announced in 1917, the numbers of the nebulæ in the N.G.C. being 6946, 4527, 4321, and 224 (the great nebula in Andromeda, three new Novæ in this). The Nova in the first of these was found by Ritchey, and those in Nos. 4527 and 4321 were detected on plates exposed in 1915, the discovery being made through a comparison with plates taken in 1901 (*L.O.B.*, 300). One Nova in the Andromeda nebula was found by Shapley on plates taken at Mount Wilson 1917 September 11, the other two by Ritchey on plates taken there in 1909. Five suspected Novæ are announced in other nebulæ. H. Shapley in *Pub. Ast. Soc. Pac.*, 29, 213, gives a list of 11 Novæ, of which he writes: "Six of these objects are situated in spiral arms, three in denser nuclear parts, and the other two apparently at some distance from nebulosity, but longer exposures would probably show connecting spiral arms." That this apparent relationship between Novæ and spiral nebulæ in so many instances can be fortuitous is unthinkable. The Novæ must almost certainly be *in* the nebulæ, and this circumstance, taken in conjunction with the well-known clustering of Novæ in our galaxy towards the galactic plane, seems highly significant, and gives striking support to the theory that the spirals are "island universes."

T. E. R. P.

Stellar Distribution and Motions.

Parallaxes.—The stellar parallaxes published recently are exceptionally numerous. *Pub. Yerkes Obs.*, **4**, pt. 1, contains the details of 85 determinations made with the 40-inch telescope by Slocum, Mitchell, Joy, Lee, and van Biesbroeck, but in most cases the results had already been announced. Parallaxes of 50 stars, including a large proportion of binaries, are given by J. A. Miller in *Sproul Obs. Pub.*, **4**. A list of 83 results obtained at the Leander M'Cormick Observatory is given by S. A. Mitchell in *Pop. Ast.*, **25**, 23. A high standard appears to have been attained in these determinations, the probable error being usually less than $0''\cdot01$.

The determination of the parallaxes of double stars with known orbits is important on account of the information which it gives as to the masses of stars. The Sproul parallaxes are mostly small, and consequently the derived masses are subject to large uncertainty; but even so, the results confirm the view that the range of masses is very small. More definite information is obtained by the redetermination with greater accuracy of the values for some stars well known to have large parallaxes. Among these may be mentioned 70 Ophiuchi with combined mass $1\cdot22 \times$ Sun according to Slocum, or $1\cdot91 \times$ Sun according to Miller, and η Cassiopeiæ with mass $1\cdot21$ according to Miller. Mitchell's parallax $0''\cdot309$ for Procyon gives a mass about $1\cdot3$. In this connection may be mentioned H. N. Russell's determination of the mass of Krueger 60 *comes* (*A. J.*, No. 711); he finds that it is between $\frac{1}{6}$ and $\frac{1}{8}$ of the Sun's mass, and it is thus the least massive star known.

With the 60-inch reflector at Mount Wilson observations for parallax of some planetary nebulæ are being made. In one case, N.G.C. 7662, A. van Maanen has found a sensible parallax $0''\cdot021 \pm 0''\cdot004$ (*Pop. Ast.*, **25**, 381); but in view of the very small proper motion, $0''\cdot003$, relative to comparison stars, this result seems to require confirmation. If accepted as it stands, the diameter of the nebula would be about twenty times that of the orbit of Neptune. Another planetary nebula, N.G.C. 5194, and two Wolf-Rayet stars were found by van Maanen to have insensible parallax.

A useful compilation of the parallaxes of 625 stars taken from all sources has been made by O. R. Walkey (*Jour. B. A. A.*, **27**, *Appendix*). This is on the lines of the well-known *Groningen Pub.*, No. **24**, but brought up to date. Only the mean results for each star are given, but there are references to the sources where the results of individual observers may be found. Another compilation, published as a pamphlet by T. E. Heath, is somewhat differently arranged, and contains about 100 additional stars, including some of Adams's spectroscopic determinations of distance.

A further list of 21 parallaxes found by the spectroscopic method is given by W. S. Adams in *Pub. Ast. Soc. Pac.*, **28**, 279.

These are for stars whose distances have already been measured by the direct method, and the agreement is good.

A. van Maanen (*A. J.*, No. 723) gives parallaxes for 60 stars, determined with the 60-inch reflector at Mount Wilson. W. S. Adams and A. H. Joy (*Ap. J.*, **46**, 313) give the luminosities and parallaxes of 500 stars determined by the spectroscopic method.

Estimates of the distances of very remote objects, such as the globular clusters and spiral nebulæ, have been made recently by indirect methods. If in any way the absolute magnitude of a star can be estimated, its apparent brightness gives at once a knowledge of its distance. The spectroscopic method of determining distances is an attempt to apply this principle precisely, the absolute magnitude being inferred from the relative intensities of certain spectral lines. Another very favourable application occurs in those globular clusters which contain a large number of variable stars. It is found that in each cluster the variables are very uniform in brightness, the average deviation from the mean being less than a tenth of a magnitude. Any systematic difference in the apparent brightness from one cluster to another must therefore be attributed to a difference of distance, and in this way the relative distances of the clusters can be determined very accurately. The absolute scale of these distances can only be found when we know the absolute brightness which these variables conform to, and this must be obtained from a study of the corresponding variables in our own galactic system. Although this is not yet very certainly known, the evidence is sufficient to show that the clusters are very remote. H. Shapley has further found that the magnitudes of the brightest stars in the clusters afford in a similar way a measure of their distances, and it appears that with one or two exceptions the distances are all above 10,000 parsecs (*Proc. Nat. Acad. Washington*, **3**, 479). In a popular account (*Pub. Ast. Soc. Pac.*, **29**, 245) Shapley gives 14,000 parsecs for the distance of Messier 3, with an estimated uncertainty less than 20 per cent.; within a sphere of 10 parsecs radius 15,000 stars are counted which must all be at least two magnitudes brighter than the Sun, as compared with only 4 or 5 stars of this brightness in a corresponding volume in our own neighbourhood.

In a similar manner H. D. Curtis (*L.O.B.*, **9**, 108) has estimated the distances of the spiral nebulæ, using the magnitudes of the novæ which have appeared in them as a criterion. Six novæ have been detected in the spirals, four of which attained magnitude 14, and two were rather brighter. Of the 27 novæ in our own galaxy the average magnitude at maximum was about 5^m. As we have presumably detected only the very brightest novæ in the spirals, it would appear that the nearest spirals must be at distances some 100 times greater than the dimensions of the galaxy, and they are therefore bodies comparable in size with our stellar system.

Proper Motions.—As usual, many lists of stars with moderately

large proper motions have been published. Two lists from Greenwich Observatory are given in *M.N.*, **77**, 204, 218. *Pub. Cincinnati Obs.*, No. 18, contains an extensive catalogue of proper motion stars. Many proper motions are given by R. T. A. Innes in the *Union Observatory Circulars*, and by M. Wolf at frequent intervals in the *Ast. Nach.* The two specially interesting stars of large proper motion found last year by Barnard and Innes are the subject of a separate Council Note. A. van Maanen (*Pub. Ast. Soc. Pac.*, **29**, 258) has found a star with proper motion $3''{\cdot}01$ near Lalande 1299 (but not associated with it). The companion to P. $2^h{\cdot}123$ mentioned last year has been found by Shapley to have an absolute visual magnitude $12^m{\cdot}3$ and a colour index $1^m{\cdot}74$, which clearly indicates type M. A remarkable example of stars widely separated in the sky possessing a common proper motion has been found by M. Wolf in the neighbourhood of 23 Ophiuchi; two star-pairs 4° apart each have an annual motion $1''{\cdot}25$ in position-angle 220° (*Observatory*, **41**, 67).

Systematic Motions.—In *M.N.*, **77**, 581, Sir F. W. Dyson and W. G. Thackeray discuss the proper motions of 12,000 stars between Dec. +24° and +32° determined for the Greenwich Catalogue of 1910·0. The existence of the two star-streams is shown very clearly, but no sufficient evidence of the third stream appears. The apices determined are, for Stream I., R.A. 6^h, Dec. −8°; and for Stream II., R.A. 18^h Dec. −60°. The velocities of the streams relative to the Sun are in the ratio 5 : 3, and the number of stars belonging to them in the ratio 4 : 3. There is also a discussion of the distribution with respect to the galactic plane of proper motions between various limits of size; for stars so near that their proper motions exceed $6''$ per century no galactic concentration is manifested. In another communication (*M.N.*, **77**, 212) Sir F. W. Dyson shows that the number of proper motions above any limit s conforms very well to the tentative theoretical law $c^2/(c^2+s^2)$, where c is a constant, and hence derives the distribution of these stars as regards distance.

By using the spectroscopic absolute magnitudes of 700 stars of known radial velocity W. S. Adams and G. Strömberg have been able to produce greatly extended evidence of a progressive increase of speed of stars as the absolute brightness diminishes (*Ap. J.*, **45**, 293). The increase amounts to about 1·5 km. per sec. for a step of one magnitude. (This refers to one component; the increase will be doubled if the speed in three dimensions is considered.) When account is taken of the different average brightness of the spectral types, the old relation between speed and type seems to be almost swallowed up in this new generalisation. There is, however, a small residual dependence on type which survives when a comparison is made for stars of the same absolute magnitude.

In *Ap. J.*, **46**, 176, C. D. Perrine has found some evidence of preferential motion in the radial velocities of planetary nebulæ.

The prolateness, 1·76, agrees well with values found from stellar motions, but the data are at present very meagre.

In *A. J.*, No. 718, H. Raymond has made a solution from the Boss proper motions for determination of the three ellipsoidal axes of the velocity-distribution. He separated the stars according to spectral type, and his results show some measure of agreement, but also some curious discordances, from similar discussions of the radial velocities. In particular, he finds that for all types the least axis of the ellipsoid is directed towards the galactic pole, whereas Eddington and Hartley found no systematic tendency in the orientation of the two smaller axes, and Gyllenberg found the least axis was directed 90° away from the galactic pole. A somewhat similar discussion by S. Oppenheim (*Ast. Nach.*, No. 4896) treats the stars as a whole without separation in types. C. D. Perrine (*Proc. Nat. Acad. Wash.*, 3, 491, *Ap. J.*, 46, 266) discusses the complicated relations between preferential motion, spectral class magnitude, and velocity. Special studies of the distances and velocity-distributions of stars of types A, F, and O are given respectively by K. G. Malmquist, C. F. Lundahl, and W. Gyllenberg in *Arkiv för Mat. Ast. och Fysik*, 11, Nos. 28–30.

A very full account of the various analytical methods which have been applied to the investigation of the systematic motions of the stars is given by C. V. L. Charlier in *Arkiv M. A. och F.*, 12, No. 10.

Stellar Dynamics.—C. V. L. Charlier (*Lund Meddelanden*, Series 2, No. 16) has given a full treatment of the theory of stellar motions according to the methods of statistical mechanics usually applied to the theory of gases. This theory lays importance on the small deflections of stars by chance encounters, and is applicable if the age of the stellar universe approaches the *time of relaxation*, which is found by Charlier to be of the order 10^{16} years. The theory adopted by Jeans and Eddington assumes a much shorter time-scale. In *Scientia*, 1917 August (translated in *Observatory*, 40, 387), Charlier brings forward some evidence that the stellar universe has approached considerably towards the statistical equilibrium assumed in his theory, and replies to criticisms that have been raised. In *Arkiv M. A. och F.*, 12, No. 21 he obtains independently the result proved by Jeans that, if an oblate system can be in equilibrium under its own attraction, the velocity-ellipsoids must point in a transverse direction; he remarks that with this arrangement the average velocity increases as we go outwards from the centre of the system.

Miscellaneous.—H. Shapley has continued his researches on the colours and magnitudes of stars in globular clusters. A review of these is given in *Observatory*, 40, 394. A very interesting extension of the work is the detection of axes of symmetry in Messier 13 and other clusters by Pease and Shapley (*Proc. Nat. Acad. Wash.*, 3, 96). This is shown when either

stars of sufficiently faint magnitude are counted, or when the count is limited to the blue stars; the brightest stars and the red stars are more symmetrically distributed. The phenomenon seems to be analogous to the galactic concentration in our own system.

Progress in our knowledge of the number and galactic distribution of the stars is recorded in a separate Council Note.

A. S. E.

The Number and Galactic Concentration of the Stars.

Several papers have been published during 1917 dealing with this subject, and as the various independent investigations are in substantial agreement, the main facts now seem to be clearly established. As regards the star density averaged over the whole sky, down to magnitude limits as far as about 16, the results of the Franklin-Adams counts (Chapman and Melotte, *Mem. R.A.S.*, **60**, 145) receive general confirmation from a discussion of 65 Harvard plates, of Kapteyn's Selected Areas, by van Rhijn (*Groningen Publications*, No. **27**, 1917; *cf.* also *M.N.*, *R.A.S.*, **78**, 132). The much more rapid increase of star density with increasing magnitude which was found by Kapteyn (*Groningen Publications*, No. **18**, 1908) is explained satisfactorily by van Rhijn as a result of the excessive contraction of the magnitude scale then in use. The absolute magnitude scale, since determined at Harvard and Mount Wilson (*H.A.*, **71**, 231), has been confirmed also by Halm's investigations (*cf.* *M.N.*, *R.A.S.*, **78**, and references there given). When reduced to this scale, Kapteyn's values of the average star density come into conformity with those already mentioned: his results for the galactic concentration, and its increase with magnitude, are also modified and diminished, agreeing generally with van Rhijn's, and still exceeding the very small increase found by Chapman and Melotte. Seares (*Proc. Nat. Acad. Sci.*, **3**, 217), in a preliminary discussion of the total counts on 88 Mount Wilson plates of the Selected Areas (limiting magnitude nearly 18), also finds a much larger value of the galactic concentration than will fit in with the results given by the latter authors. Van Rhijn points out an error in the method of reduction used by them, which would tend to minimise their determination of the galactic concentration. The error is admitted by them, and upon newly reducing their data (*M.N.*, *R.A.S.*, **78**, 66) they find results in good accordance with those of van Rhijn. Thus the general character of the galactic concentration is now agreed upon by Kapteyn, van Rhijn, Seares, and Chapman and Melotte. Seares (*Ap. J.*, **46**, 117) finds that Professor Turner's counts of stars upon the astrographic plates also confirm the same conclusions.

S. C.

Stellar Spectroscopy in 1917.

Nebulæ.—In a note on the forms of spectral lines observed in the planetary nebulæ N.G.C. 7662 and 2392, W. W. Campbell and J. H. Moore describe some remarkable observations, which appear to be characteristic of nebulæ given in the Harvard classification (*H.C.O. Ann.*, **76**) as Pe, or those in which the line at 4686 appears strong. The nebulium lines at 4959 and 5007 appear double; the components are separated by about 0·8 A, an effect which is apparently independent of the position of the slit with respect to the major axis of the nebula. There is considerable variation in the relative intensities of the components in the different positions. For possible explanation, the authors have looked without success for signs of a Zeeman effect; and among other hypotheses, while a possible Stark effect is not yet excluded, the authors favour the view that the dark medial line is a reversal produced by the outer layers against a broadened line originating in the interior of the nebula. The double lines are also inclined in a way which is interpreted as due to a fairly rapid rotation of the central part of the nebula, with smaller velocities in the outer strata. The measures taken, together with van Maanen's parallax 0″·023, indicate a mass for N.G.C. 7662 about 7·3 ⊙ (*A.S.P.*, **29**, 133).

The planetary nebulæ N.G.C. 6543 and 7009 have been studied in interesting detail by W. K. Green (*L.O.B.*, **9**, 92). By placing the slit of the spectroscope in 8 different position angles on each of the nebulæ, and by study of the curved lines recorded, the velocities at about 50 points in N.G.C. 6543 and more than 70 points in N.G.C. 7009 were obtained. (The former nebula is classified by the Harvard observers as Pd, and a special search was made in vain for signs of doubled lines, such as had been found characteristic of nebulæ of the class Pe.) The evidence points to a rotation about the shorter axis accompanied by irregular local velocities. Photometric measures have been also made from photographs of the same nebulæ, and comparison is made between the results thus obtained and the intensities to be expected from ellipsoidal shells of non-absorbing luminous gas.

Attempts have been made to determine the parallax of certain nebulæ. For the Ring Nebula in Lyra, N.G.C. 6720, a value 0″·015 ± 0″·007 has been found by B. L. Newkirk (*L.O.B.*, **9**, 100). For the same nebula van Maanen finds a value 0″·002 ± 0″·005 (*A.S.P.*, **29**, 209).

For the nebula Messier 51 (N.G.C. 5194), the spiral nebula in Canes Venatici, the central star has been used by van Maanen for a parallax determination by reference to eight comparison stars. The value found for the relative parallax is 0″·000 ± 0″·010 (*A.S.P.*, **29**, 182).

For the planetary nebula N.G.C. 7662 van Maanen derives a parallax 0″·023, corresponding to a distance of about 140 light years (*Proc. Nat. Acad. Washington*, **3**, 133).

The following references may be made to more comprehensive work on nebulæ:—

"Photographs of Nebulæ with the 60-inch Reflector, 1911–1916," by F. G. Pease (*Ap. J.*, **46**, 24), relating to 90 nebulæ, of which 34 are illustrated by photographic reproductions.

"The Nebulæ," by H. D. Curtis (*A.S.P.*, **29**, 91), one of the Adolfo Stahl lectures at San Francisco.

"Some Relations of the Spiral Nebulæ to the Milky Way," by R. F. Sandford (*L.O.B.*, **9**, 80).

"Messier's Catalogue of Nebulæ and Clusters," by H. D. Curtis (*A.S.P.*, **29**, 177), a useful and complete compilation, giving the equivalent reference number in the N.G.C., the R.A. and Dec. (1900), and the Galactic Longitude and Latitude and a brief description.

Novæ.—The year is remarkable for an outburst of activity among the astronomers of the Pacific Coast in the recognition of "novæ" in spiral nebulæ. The spectroscopic test has been applied in one case, namely, the nova found in July by G. W. Ritchey in the fine spiral in Cepheus, N.G.C. 6946. A spectrogram obtained by Ritchey and Pease showed that this star of 16th magnitude has bright bands in its spectrum (*A S.P.*, **29**, 210). Ritchey calls attention to four other objects. H. D. Curtis, F. G. Pease, H. Shapley also note the appearance of novæ or variables in other spiral nebulæ. The last-named observer gives a list of temporary stars in spiral nebulæ (*A.S.P.*, **29**, 214), and it will be convenient to utilise it here for the sake of giving references briefly.

N.G.C.	Constellation.	Date of Maximum (?).	Distance from Nucleus.		
			"		
224	Andromeda	1885	16	Hartwig.	
5253	Centaurus	1895	32	Mrs. Fleming	*H.C.O. circ.* 4.
4321	Com. Ber.	1901	110	Curtis	*A.S.P.*, **29**, 181.
3147	Ursa Major	1904	340	Mrs. Roberts.	
224	Andromeda	1909	249	Ritchey	*A.S.P.*, **29**, 212.
224	Andromeda	1909	198	Ritchey	,, ,, 212.
2841	Ursa Major	1912	54	Pease	,, ,, 213.
4321	Com. Ber.	1914	111	Curtis	,, ,, 181.
4527	Virgo	1915	45	Curtis	,, ,, 181, 206.
6946	Cepheus	1917	111	Ritchey	,, ,, 210.
224	Andromeda	1917	600	Shapley	,, ,, 213.
224	Andromeda	1917	256	Ritchey	,, ,, 257.

H. D. Curtis (*L.O.B.*, **9**, 108) estimates the distance of the spiral nebulæ by comparing the magnitudes of the brighter novæ, which may be presumed to be in our galaxy, with those of the faint novæ now found in the spiral nebulæ (see above, p. 311).

Faint nebulosity has been observed on photographs of Nova Persei (1901) taken at Mount Wilson Observatory by F. G. Pease and by G. W. Ritchey (*A.S.P.*, 29, 256). The fan-shaped appearance of the nebulosity resembles in many ways a form which was seen in the original outburst in the later months of 1901, the distance from the nova now being one-tenth that of the earlier outburst. Ritchey also describes a sharply-defined, nearly circular ring round the nova, about 16″ in diameter, and he suggests that it may be connected with the sudden increase of brightness noted in 1917 August by Belopolsky (*Harv. Bull.*, 643).

The spectrum of Nova Persei is reported by W. H. Wright (*A.S.P.*, 29, 217) to have been photographed in 1914 September. The record shows a continuous spectrum extending with great uniformity far into the ultra-violet. There are four emission bands, probably H_δ, H_γ, H_β, and 469 $\mu\mu$.

Special Studies.—The spectra of nine double stars have been studied by W. S. Adams and A. H. Joy (*A.S.P.*, 29, 182). In only two instances is the brighter component of more advanced type.

Two other stars of helium type have been found by the same observers (*A.S.P.*, 29, 112) to have bright hydrogen lines in their spectra, viz. Groom. 515 (type B4) and Boss 1215 (type B5).

The two stars *ν Geminorum* and *β Canis Minoris* of classes B5 and B8 are noted by P. W. Merrill (*Detroit Obs.*, 2, 181) as having the hydrogen line H_α bright.

Under the direction of Professor Hussey the second volume of the publications of the Detroit Observatory contains some important work of varied nature, illustrated by striking reproductions of stellar spectra made by R. H. Curtiss. Attention should be here called to the following sections of the volume:—

The spectrum of *γ Cassiopeiæ*, by R. H. Curtiss, p. 1.
The spectrum of f_1 *Cygni*, by R. H. Curtiss, p. 35.
The spectrum of *H. R.* 985, by R. H. Curtiss, p. 39.
A spectrum of the *P. Cygni* type, by P. W. Merrill, p. 71.
The spectrum of *ρ Leonis*, by B. H. Dawson, p. 158.

Other sections in the volume are referred to in the paragraph below on *Classification.*

The origin of certain bands in stellar spectra at wave-lengths near the limit of atmospheric transmission has been successfully discovered by A. Fowler and R. J. Strutt, and is referred to in the paragraph below relating to *Work in the Laboratory.*

Spectroscopic Parallax.—The very remarkable memoir "On the Luminosities and Parallaxes of 500 Stars," by W. S. Adams and A. H. Joy (*Ap. J.*, 46, 313), calls for a special paragraph in these annual notes. The work deals with 1520 photographed spectra relating to 500 stars; the attempt has been made as far as possible to secure at least three photographs of each star, in order

to avoid the uncertainties due to under-exposure or over-exposure or peculiarities in plate-grain. Success in this aim has been accomplished for all except 122 stars, and of these 106 are represented by two plates each. In the list of 500 stars there are 360 with measured parallaxes, and the mean difference between the spectroscopic and the trigonometric values of the parallax is +0″·0037. If comparison is limited to the 59 stars with parallaxes measured by three or more observers, the mean difference is +0″·001.

Of the 500 stars, 441 have spectral determinations by the Harvard observers. And comparison in the case of the brighter stars shows that the Mount Wilson observers differ from the Harvard observers by only half a tenth of a spectral division in their estimates, and by 1·2 division in their measures.

Particularly interesting is the direct evidence afforded bearing on the division of stars into the classes giant and dwarf. The division is shown conspicuously in the types from F onwards to M. The giants and dwarfs are grouped about the following mean absolute magnitudes respectively:—

	F	G	K_0-K_3	K_4-K_9	M
Giants	+1^m·1	+0^m·6	+1^m·3	+1^m·4	+1^m·6
Dwarfs	+4·1	+5·3	+6·3	+7·8	+10·8

The main table of results, which is arranged with admirable conciseness and completeness, contains a column in which is entered the luminosity of each star in terms of the Sun as unity, the value +5·0 being taken as the Sun's absolute magnitude.

The stars of high luminosity are characterised by spectra in which both the hydrogen lines and the enhanced lines are abnormally strong.

It is interesting to note the prominent part played by the elements strontium and calcium in affording special lines sensitive enough for the discrimination of absolute magnitudes, especially in the case of stars of class F.

Classification.—Under this heading reference may be made to the following contributions:—

An investigation of the spectra of stars belonging to the class R of the Draper classification, by W. Carl Rufus (*Detroit Obs.*, 2, 103) dealing with the relation of stars of class N to those of class R.

Spectroscopic observations of stars of class Md, by P. W. Merrill (*Detroit Obs.*, 2, 45).

Radial Velocity.—Remarkable radial velocities have been found in the following stars by W. S. Adams and A. H. Joy:—

	Mag.			μ.
A.G. Ber. B. 1366	8·9	F0	+339 km./sec.	0″·51
A.G. Ber. A. 1866	9·0	F9	−190	0″·7

Variable Radial Velocities.—Variable radial velocity has been found in the following southern light-variables :—

	Class.			
U Hydræ	III. Irreg.	N	G. F. Paddock	*L.O.B.*, 9, 68.
T Carinæ	Susp.	Ko	,,	,,
S Muscæ	IV. Cepheid	F8p	,,	,,
T Centauri	II. Long	Md	,,	,,
R Apodis	Susp.	Ko	,,	,,
ι Libræ	III.	Aop	,,	,,
R Tri. Aust.	IV. Cepheid	K5–G5	,,	,,
S Tri. Aust.	,,	G5	,,	,,
S Normæ	,,	Go	,,	,,
RV Scorpii	,,	F5–G5	,,	,,
RS Sagittarii	V. Algol	B5	,,	,,

Variable velocity has also been found in the following stars by W. S. Adams and A. H. Joy (*A.S.P.*, 29, 113 and 259) :—

Boss 1131, 1275, 2193, 4573, 4669, 4821, 5150, 5160, 5890, 6129, and A. G. Camb. 3591, 6486.

Spectroscopic Binary Stars.—Orbits are given for the following stars :—

					P.	*e.*
γ Phœnicis	K5	R. E. Wilson	*L.O.B.*,	9, 116	193^{d}·79	0·005
σ Puppis	K5	,,	,,	9, 117	257·8	·017
κ Pegasi (bright Component)	F?	F. Henroteau	,,	9, 120	5·9715	·03
β Cephei	B1	C. C. Crump	*Detroit Obs.*,	2, 144	0·19	·04
ζ_1 Ursæ Maj.	Ap	L. Hadley	,,	2, 76	20·53	·53

The visual binary of κ *Pegasi* was discovered by Burnham in 1880. It has a period of 11·37 years, the components being approximately of 5th magnitude. One of the components was found by Campbell in 1900 to be a spectroscopic binary. Observations made at the Lick Observatory in 1900 and 1912, and continued there in 1917 by Henroteau, have led to a decipherment of the elements of a very interesting system (*L.O.B.*, 9, 120). It appears that the system consists of a spectroscopic binary of total mass 10·33 ⊙—viz. a bright body, and a dark body whose spectrum has not been detected. The bright body in this spectroscopic system is observed as one of the components of the visual pair. And there is another bright body which is the other component of the visual pair; it has a mass 4·00 ⊙, and its orbit, referred to the centre of mass of the spectroscopic system, has a semi-major axis 1826×10^6 km. If it may be assumed that the planes of the two orbits (visual and spectroscopic) coincide, it appears that the masses of

the components of the spectroscopic binary would be 6·62 ⊙ (bright) and 3·71 ⊙ (dark), whilst the semi-major axis of orbit of the bright body would be $6{\cdot}7 \times 10^6$ km. There is evidence of a revolution of the line of apsides in a period approximately equal to that of the visual pair.

Work in the Laboratory.—Bands discovered in 1890 by Sir W. Huggins in the spectrum of *Sirius* at wave-lengths near the limit of atmospheric transmission have been traced to their origin, viz. ozone in the terrestrial atmosphere, by an admirable research of A. Fowler and R. J. Strutt (*R.S. Proc.*, **93**, 577). The bands were observed also at Potsdam by Hartmann in 1904 in the spectra of *α Aurigæ*, *α Lyræ*, *β Orionis*, and *ζ Tauri*, and again in 1915 at Edinburgh by Professor Sampson in the spectra of *Capella* and *Regulus*. The identification with ozone has been made in the laboratory by Fowler and Strutt by experiments with dilute ozone in tubes varying in length from 8 feet to 18 inches interposed between the slit of a quartz spectrograph and the incandescent crater of a carbon arc or burning magnesium. The wave-lengths of the bands have been measured, and also directly compared with the corresponding bands not only in the stellar spectra but also in the spectrum of the Sun at various altitudes varying from 55° to 1°.

The spectrum of oxygen has been studied by A. Fowler and J. Brooksbank (*M.N.*, **77**, 511) between the wave-lengths 2000 and 7000, under varied conditions of pressure and electrical discharge. Some of the lines, elicited only by the strongest discharge, are shown to coincide with stellar lines found in certain Helium stars and in a Wolf-Rayet star. The authors agree with Roscoe and Schuster in assigning a line at 5592 to oxygen rather than to carbon, to which Merton ascribes it.

The spectra of 30 meteorites have been examined by photographic methods involving new and ingenious devices by Sir W. Crookes (*Phil. Trans.*, A, **217**, 411).

Further contributions on the study of the pole effect are made by C. E. St. John and H. D. Babcock, who have studied the effect in electric arcs of different constants, and find a certain form which is free from the effect in its central zone (*Ap. J.*, **46**, 138).

The cause of the pole effect is still not understood. Critical remarks are made by T. Royds (*Ap. J.*, **45**, 112) and by H. G. Gale (*ibid.*, **45**, 142).

Instruments.—Sir William Crookes describes details of his device for a slit with jaws of quartz, with which he has secured remarkably fine spectra (*Phil. Trans.*, A, **217**).

A new form of spectrocomparator has been devised by DeLury (*Ap. J.*, **45**, 278).

The new quartz spectrograph for use in connection with the Crossley Reflector at the Lick Observatory is described by W. H. Wright (*L.O.B.*, **9**, 52).

W. E. Forsythe (*Ap. J.*, 45, 278) calls attention to a mode of mounting and rotating prisms of constant deviation.

A photograph illustrating the state of the 100-inch reflector of the Mount Wilson Solar Observatory in October 1917 is given as a frontispiece of the December number of the *A.S.P.*, 29, and in a note on p. 262 it is stated that the mirror is now in position and preliminary tests are in progress.

Methods of Reduction of Observations.—In a brief note (*A.S.P.*, 29, 195) F. Henroteau describes two short methods for computing the orbit of a spectroscopic binary star by use of the Allegheny Tables of Anomalies.

H. F. N.

The Astrographic Catalogue.

The last notice of progress of this work appeared in the Annual Report of 1916 February. The present note is a statement of the additions to the printed volumes that have appeared since that date, and may be read in conjunction with the tabular statement in the report for 1913 February, which shows the range of work undertaken by the co-operating Observatories.

The second volume of the Rome Zone, containing the measures of the plates whose centres are at declination $+63^\circ$, has been published. The funds for the reduction of the $+64^\circ$ Zone, which forms the first volume, were provided by Mr. A. F. Lindemann, a Fellow of the Society, and the success of that volume induced the authorities of the Vatican to continue publication. The actual work of reduction and publication is being done in England under the supervision of Professor Turner, the plates being measured at Rome. Eight such volumes will complete the series.

The Catania Observatory has published a volume (vol. 3, part 1) covering the region in declination $+48^\circ$ to $+50^\circ$, R.A. 0^h to 3^h, which is the sixth of such parts that have already appeared, all of R.A. 0^h to 3^h; two more are required to complete this block of right ascension, so that sixty-four parts such as these will complete the whole zone allotted to Catania. A third volume of the Helsingfors Catalogue has appeared, covering the whole breadth of the Helsingfors Zone (plate centres $+46^\circ$ to $+40^\circ$), and as two similar volumes for R.A. 6^h to 9^h and 9^h to 12^h have been already published, about three-eighths of this section is completed. The name of Mr. Furuhjelm, the Sub-Director of the Astrographic Department, appears on the title-page of this volume with that of Professor Donner. It seems that the latter has given up, or may shortly be giving up, superintendence of the work, but he has ensured its continuance by personally providing a considerable sum of money sufficient to pay all expenses for twelve years. It appears that the cost of the volumes already published has been partly met by Professor Donner out of his private means. The volumes recently published by French Observatories are Paris,

Tome 4, which comprises the whole zone of plates whose centres are at declination $+21°$. Three similar volumes containing the plates, with centres at declination $+22°$, $+23°$, and $+24°$, have already appeared: Bordeaux, Tome 4, whole zone, plate centres $+14°$; Toulouse, plate centres $+5°$, R.A. 6^h to 24^h. These with the sections published by the Algiers Observatory complete about half the zones (plate centres $24°$ N. to $2°$ S.) allotted to the four French Observatories. In the southern hemisphere the Tacubaya Observatory has begun publication, and the first volume of the Zone $-10°$ to $-16°$ (plate centres) appeared in 1916. The form adopted by this Observatory is not dissimilar to that of the Helsingfors Catalogue. The measured co-ordinates are given, the standard co-ordinates are shown, and, finally, the accurate right ascension and declination of every star is computed from these. All the stars on every plate are measured. The number of the star in the Bonn Durchmusterung and its magnitude from that work are added when possible, so that it is easy to make comparison of the places of a star which appears on contiguous plates, and a cursory comparison of this nature gives assurance of accuracy.

Volume 4 of the Cape Astrographic Zones has been passed for press since our last report, but some sheets were destroyed by a fire at the printers in Edinburgh, and the volume has not yet been distributed. Other MS. is ready for the printers, but is stored until normal times again prevail, and ordinary Government printing is resumed. To this record of the actual volumes that have appeared, it may be added that at the Nizamiah Observatory, Hyderabad, the work of the zone (plate centres $-17°$ to $-20°$) is being dealt with energetically, and that the whole of the copy for press of the Zone $-17°$, which comprises 180 plates, and part of the Zone $-18°$, are at the printers.

It may be added that at some Observatories — Greenwich, Helsingfors, Potsdam, and possibly others—the work is being extended by determining the Proper Motion of stars by direct comparison of two plates taken at an interval of several years. Some results of this nature have been published by M. Furuhjelm of Helsingfors. H. P. H.

List of Public Institutions and of Persons who have contributed to the Library, etc., since the last Anniversary.

His Majesty's Government in India.
The Lords Commissioners of the Admiralty.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Institution of Electrical Engineers.
London, University College.
Meteorological Office.
National Physical Laboratory.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Belfast, Natural History and Philosophical Society.
Bradford, Libraries, Art Gallery and Museums Committee.
Cambridge Observatory.
Cambridge Philosophical Society.
Chatham, Royal Engineers' Institute.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Edinburgh, Royal Society.
Glasgow Observatory.
Leeds Astronomical Society.
Manchester Astronomical Society.
Manchester Literary and Philosophical Society.
Oxford, Radcliffe Observatory.
Oxford, University Observatory.
Stonyhurst College Observatory.
Arcetri, Reale Osservatorio.
Barcelona, Sociedad Astronomica.
Basel, Naturforschende Gesellschaft.
Calcutta, Astronomical Society of India.
Canada, Royal Society.
Cape of Good Hope, Royal Observatory.
Cape Town, Royal Society of South Africa.
Cape Town, South African Association for the Advancement of Science.
Catania, Società degli Spettroscopisti Italiani.

Chicago, Society for Practical Astronomy.
Cincinnati Observatory.
Copenhagen, Observatorium.
Cordoba, Observatorio Nacional Argentino.
Dijon, Académie des Sciences, Arts et Belle Lettres.
Evanston, Illinois, Dearborn Observatory.
Geneva, Société de Physique et d'Histoire Naturelle.
Halifax, Nova Scotian Institute of Science.
Harvard College Astronomical Observatory.
Helsingfors, Finska Vetenskaps Societet.
Hobart, Royal Society of Tasmania.
Houston, Texas, Rice Institute.
Hyderabad, Nizamiah Observatory.
India, Survey Department.
India, United Service Institution.
Japan, Astronomical Society.
Johannesburg, Union Observatory.
Kasan, Observatoire Astronomique de l'Université.
Kodaikánal and Madras Observatories.
La Plata, Observatorio Astronomico.
Lick Observatory.
Lisbon, Academia das Sciências.
Lisbon, Observatorio Astronomico.
Lund, Astronomiska Observatorium.
Madrid, Associacion Española para el Progreso de las Ciencias.
Madrid, Real Academia de Ciencias.
Marseille, Observatoire.
Mauritius, Royal Alfred Observatory.
Melbourne Observatory.
Milan, Reale Osservatorio di Brera.
Missouri University, Laws Observatory.
Montpellier, Académie des Sciences et Lettres.
Mount Wilson, Solar Observatory.
Mozambique, Servicos de Marinha.
Neuchatel, Observatoire Cantonal.
New Zealand, Department of Lands and Survey.
Ottawa, Dominion Astronomical Observatory.
Paris, Académie des Sciences.
Paris, Bureau des Longitudes.
Paris, Ministère de l'Instruction Publique.
Paris, Société Astronomique de France.
Paris, Société Mathématique de France.
Paris, Société Philomathique.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Princeton, University Observatory.
Pulkovo, Observatoire Central Nicolas.
Rio de Janeiro, Observatorio.
Rome, Reale Accademia dei Lincei.

Rome, Specola Vaticana.
San Francisco, Astronomical Society of the Pacific.
Stockholm, Observatorium.
Swarthmore College, Penn., Sproul Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya, Observatorio Astronómico Nacional.
Tokyo, Observatoire Astronomique.
Toronto, Royal Astronomical Society of Canada.
Tortosa, Observatorio del Ebro.
Toulouse, Observatoire Astronomique.
Travancore Observatory.
Turin, Reale Accademia delle Scienze.
Turin, Società Urania.
Washington, Carnegie Institution.
Washington, National Academy of Sciences.
Washington, Navy Department.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Wellington, Hector Observatory.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editor of the "Astronomischer Jahresbericht"
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editor of Brown's Nautical Almanac.
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Nature."
Editors of "The Observatory."
Editors of "Popular Astronomy."
Editor of the "Revue du Ciel."
Editors of "Terrestrial Magnetism."

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ADDRESS

Delivered by the President, Major P. A. MacMahon, on the award of the Gold Medal of the Society to Mr. John Evershed.

The Gold Medal has this year been awarded by the Council to Mr. John Evershed, F.R.S., F.R.A.S., for his investigations of Radial Motion in Sun-spots and other contributions to Astrophysics. It becomes my duty, which I regard also as a privilege, to give you some account of the work which has caused the Council to come to this decision.

The above-mentioned short title of his claim to recognition mentions specifically one achievement. For the rest, he has done much in regard to prominence observations, the spectra of sun-spots in general, the reversing layer, the minute displacements of lines at all parts of the Sun's disc from the centre to the limb, eclipse and comet observations, and the invention and perfection of instruments of observation and measurement.

Prominence Observations.

In 1868 there occurred the discovery by Janssen and Lockyer that solar prominences can be seen at any time by combining the spectroscope and telescope, and that a total solar eclipse is not a necessary condition. The pioneer work of these observers, and also of Huggins, inspired many others, including our medallist, to make a systematic study of the prominences.

He commenced his astronomical life at Kenley, in Surrey, in 1890 with the aid of a small telescope and a spectroscope of his own construction. It is recollected by some of his friends that he was early led to see the possibility of photographing the prominences by the method which was so successfully introduced by Hale in 1892, whereby it became possible to photograph prominences daily, not only at the limb but all over the Sun's disc. There is little doubt that Mr. Evershed would have arrived at this instrument, known as a spectroheliograph, by his own work, and he in fact was very soon able to design and construct one himself, and bring it into daily use at the Kenley Observatory. During sixteen years he recorded 11,000 prominences, giving all the details that would be necessary for a subsequent discussion. He also devised the Evershed solar spectroscope, which has been of great value to other observers of solar phenomena.

In 1906 he was wisely chosen to be Chief Assistant at Kodaikánal Observatory, in the Madras Presidency, under the Chief Directorship of Mr. Michie Smith, and thenceforward he ceased to be an amateur. He succeeded to the Chief Directorship in 1911.

At Kodaikánal since 1904 a complete record of these apparitions had been made, the drawings representing the entire limb of the Sun. Moreover, in 1905 a spectroheliograph had been installed, and thenceforward the daily photographs were compared with the drawings.

On arrival in India Mr. Evershed found a good opportunity to continue the Kenley work, and in 1908, by making a new camera slit, he was able greatly to improve the quality of the spectroheliograms. The prominences recorded during the years 1904–14 numbered nearly 60,000, and these, supplemented by the 11,000 of Kenley, formed the subject of an exhaustive and very important Memoir by Mr. and Mrs. Evershed, published in 1917.*

Important features of the observational data should be noted. All prominences down to the smallest visible are recorded, whereas at most other observatories only those of 30″ and over are included. It was in fact found that many prominences make up in brightness what they lack in height, and their inclusion has been found to be of significant import. Another point is that activity has been expressed both by the number of prominences visible and by profile area.

Periodicity.—The period covered by the Indian records is the length of an average sun-spot cycle, and a comparison is first made between prominence and sun-spot activities during this period. The prominence curve bears a close resemblance to the sun-spot curve, but it is found that prominence maximum is reached earlier than sun-spot maximum and is longer sustained. The two forms of solar activity run through much the same changes in the same period of eleven years, and the correspondence is equally close if the northern and southern hemispheres be considered separately.

Distribution in Latitude.—Results are found in regard to distribution in latitude which are in general agreement with those found by the Italian observer Ricco in 1891, and later confirmed by Sir Norman Lockyer and Dr. Lockyer.

Distribution East and West.—Much material is available for the discussion of the puzzling facts concerning the distribution of prominences East and West. East and West merely indicate the aspect of the prominence from Earth on a given date, and the subject received little attention until the appearance of Mrs. Maunder's paper, "An Apparent Influence of the Earth on the Numbers and Areas of Sun-spots." This paper caused Mr. Evershed to give a great deal of attention to the relative frequency of solar phenomena on the eastern and western sides. According to the Kodaikánal records, the eastern prominences are not only more numerous (about 53 per cent. of the whole), but they are also more active and denser. The eastern excess is also found in prominences photographed on the disc.

Moreover, line displacements in prominence spectra are more frequently towards the red than the violet, indicating a direction

* *Memoirs of the Kodaikánal Observatory* (Madras Government Press).

away from the Earth as if the gases were repelled. Mr. Evershed discusses the matter at some length, and while finding it difficult to accept the hypothesis that the Earth exerts a damping effect upon the mighty forces at work in the Sun, admits that no better explanation is so far forthcoming. He also sought for evidence that other planets have the same kind of influence, but found none.

The east and west asymmetry of solar prominences has had new light thrown upon it during the last few days by Sir Joseph Larmor, who discusses the question in a letter to *Nature*, dated 1918 January 26. He remarks, "Although the character of the prominences can scarcely be affected by any influence of the Earth, yet their appearance may be considerably affected by their own configuration with respect to the line of sight of the observer. The outer regions of the solar atmosphere are rotating more rapidly than the parts below; if then a prominence pushed up from below into the atmosphere sloped forward in the direction of the Sun's rotation instead of being on the average perpendicular to the Sun's surface, it would present a different aspect and different depth in the line of sight to the observer according as it is on the advancing or receding side of the Sun. The darkness of the absorption markings on the disc would depend on the depth of material through which the light had to penetrate to the observer, and perhaps also in consequence the number of shadings that would be counted as markings would be affected. The amount and direction of this influence it may be hazardous to guess at, but it might just be possible to detect some slight difference in the general appearance of the markings east and west. To the bright prominences on the limb these considerations would apply in a smaller degree, if at all."

I would add that the asymmetry of the Sun's rotation appealed also subsequently to the Kodaikánal observers, as a possible cause of the asymmetry east and west of various phenomena that had been observed.

Metallic Prominences.—Prominences, as is well known, are mainly composed of H, Ca, and He, but when their bases can be examined there is found to be an occasional occurrence in the spectrum of iron and other metallic lines. These "metallic" prominences are comparatively few in number. Mr. Evershed found that the connection between them and sun-spots is not very close, but that excluding slight elevations of the chromosphere, and considering only prominences in which the common lines of sodium, magnesium, and the enhanced lines of iron are accompanied by other lines, they are almost restricted to sun-spot latitudes, and are often situated so near to sun-spots as to suggest a connection between them. The frequency curve of metallic prominences resembles that of sun-spots more closely than does that of prominences as a whole. Moreover, metallic prominences predominate on the eastern side of the Sun to a greater degree than either prominences in general or sun-spots.

Movements.—Movements in prominences are discussed at

length. There are motions in various directions due to eruptive causes, movements in the line of sight revealed by the spectroscope, and a general motion due to the Sun's rotation from east to west. The latter phenomenon is complicated by the fact that the speed of rotation varies with latitude and at different levels, it having been established by Adams at Mount Wilson that the chromosphere rotates faster than either the reversing layer or the photosphere.

Forms.—As regards form, two main classes are distinguished, viz. "large high prominences" and "prominences associated with sun-spots." The former are subdivided into four types, viz. broad massive, tapering, diffused, and prominences in rows, while the latter take three principal forms, viz. jets, rockets, and arches. This classification seems broadly to have a real significance, since the distribution both in time and latitude is not the same.

He discusses the association between prominences and sun-spots after comparing results with the drawings and articles of Fenyi in the Kalocsa Publications. He finds a general agreement, and concludes that large, massive prominences are not found directly above sun-spots, but that the rocket type is not found except above sun-spots. Prominences projected on the disc of the Sun are indicated in two different ways: first, by bright reversals of the hydrogen lines, and sometimes of metallic lines, over or near sun-spots; and, second, as remarked by Michie Smith in 1907, by absorption markings or "filaments" on the Sun's disc. The experience at Kodaikánal is all in favour of the essential identity of filaments and prominences. The filaments are distinctly shown in Hα and in calcium spectroheliograms. Several facts point to the conclusion that only specially dense prominences appear as filaments on the disc. The darkening of the D_3 helium line is also a means of tracing a prominence on the disc.

Storms.—As regards magnetic storms on Earth, a general conclusion is that they reach their maximum frequency when prominences reach the poles; this is also the time of sun-spot maximum, and it appears that the relation of magnetic storms is closer with sun-spots than with prominences.

Corona.—In 1903 Dr. Lockyer drew attention to the apparent relation between the latitudes of prominences and the form of the corona. The Kodaikánal data give general confirmation to this theory as regards the eclipses of 1898, 1900–01–05. At sun-spot maximum, when prominences are abundant all round the limb and extend to the poles, the corona is of the "dahlia" type, in which streamers are found at the poles as well as in other regions; but when, at sun-spot minimum, the prominences are confined within latitudes $\pm 60°$, the streamers are similarly restricted. An exception to this theory was, however, furnished by McClean's observations of the corona of 1908 January 3, and we must look to future eclipses for a further elucidation of the connection.

It must not be forgotten that in this work Mrs. Evershed was associated with our medallist, and that she herself drew up the report, which in every respect is a model, under the supervision

of the Director and with the assistance of Mr. S. Sitarama Ayyar and Mr. G. Nagaraja Ayyar.

It will without doubt be recognised by all Fellows of the Society that our medallist has made extensive and valuable contributions to this difficult department of solar physics.

Experiments on the Radiation of Heated Gases.

An account of these appeared in *Phil. Mag.*, series 5, vol. xxxix. They were undertaken just twenty years ago, and show the thorough way in which Mr. Evershed prepared himself for astrophysical work. They were designed to give information concerning the spectroscopic behaviour of gases and metallic vapours when heated externally to a moderate temperature. Smithells had considered the case of iodine vapour, which glows and becomes incandescent under external heating, and came to the conclusion that the luminosity was due to heating and not to chemical action. These experiments showed that this property was not peculiar to iodine. On examining the heated vapour of iodine with a spectroscope a perfectly continuous spectrum was obtained. There was no sign of resolution into lines, so that it was proved that iodine does not emit only those rays which it absorbs. Bromine and chlorine were found to behave in a similar manner. Later he added sulphur, selenium, and arsenic to the list. All these substances, when heated to a temperature at which a glass tube softens, give continuous spectra, while the corresponding absorption spectra are selective. Under the conditions that were present he came to the conclusion that there is no essential difference between gases and solids in the manner in which they radiate. He discussed the question whether molecular dissociation may not be concerned in the radiation, but saw no reason for believing such to be the case. He next proceeded to determine if sodium vapour can produce a discontinuous spectrum by external heating. He found that dense sodium vapour, when in this state, emits light of all wave-lengths, and that the change to discontinuous emission is determined by reduction of density. He found indications that at higher temperatures the continuous light would give place to bands corresponding with the absorption bands. For on watching the continuous light it is found not to fade equally at all parts of the spectrum. A stage is reached when, in addition to the D emission line, a green line appears in the place of a conspicuous absorption line, and a faint glow is observed in the blue corresponding to the absorption bands in that region.

Spectra of Sun-spots.

The application of photography to the registration of the spectra of sun-spots was very successfully developed by Mr. Evershed with the facilities at his disposal at Kodaikánal, and, in 1909, he published a valuable memoir on the subject. These photographs provided

unimpeachable data which answered questions which had been raised by the work of other observers depending largely upon less perfect observations made visually.

Two spectrographs with plane and parabolic Rowland gratings were employed in these researches. In each case was constructed a clever device for equalising the density in the photographic images of the spectrum of a spot and of the surrounding photosphere.

The spot spectrum appeared to be as constant in character as the Fraunhofer spectrum, and to consist mainly of intensified Fraunhofer lines. In fact, the great majority of the spot lines and magnesium hydride flutings are faintly shown everywhere on the Sun's disc. The spectrum is apparently the same for all spots, and is unaffected by time.

Telluric lines remain unaffected.

The spark lines are all weakened in spots, but only a small proportion of those lines which are so weakened are known to be spark lines.

The general absorption in spots is strictly continuous, and similar in character to absorption at the limb.

Comparison of the Kodaikánal spectra with the magnesium hydride spectrum, secured by Fowler, shows an agreement which may be held to justify Fowler's conclusion, that a large number of lines in the spot spectrum are due to magnesium hydride.

Radial Movement in Sun-spots.

The photographs of the spectra of sun-spots led up to the capital discovery of the radial movements in spots, which, prior to Mr. Evershed's work, had never been suspected. It is characteristic of sun-spots that in their neighbourhood there are displacements of the lines of H and Ca indicating violent movements in the line of sight. The displacements may connote either an increase or decrease of wave-length corresponding to gaseous movements of several hundred kilometres per second. They are rarely found within the umbra.

Now Mr. Evershed has discovered line displacements of quite another character. They are only found in the penumbra, are apparently permanent, and affect a large proportion of the Fraunhofer absorption lines. To explain the peculiar line displacement which takes place, it may be remarked that when the slit of the spectrograph bisects a spot and lies in the direction of the Sun's centre the spectrum lines are quite straight over the spot, but are slightly inclined as compared with lines in the neighbouring photosphere; in the centre of the umbra there is no displacement, and the inclined lines end abruptly at the edge of the penumbra. The inclination is always such that displacement towards the red corresponds with the side of the spot nearest the limb, and it vanishes when the slit lies in a direction at right angles to the line joining the spot with the Sun's centre.

The shift of the lines was so small that their measurement was

a very delicate operation. He had to design and construct a special measuring instrument, which is described in one of the Observatory Bulletins. His success appears to have been due in no small degree to this instrument.

The important discovery bears the date 1909 January 7.

From the examination and measurement of 150 spectra he was able to make the following statements:—

(i.) All the spots show line-shifts of the same order of magnitude when at the same distance from the centre of the Sun's disc.

(ii.) The shifts disappear when the spot is within about 10° of the Sun's centre, but become gradually greater as the Sun passes to about 50° from the centre.

(iii.) The displacements are towards the violet or red, according as the part examined precedes or follows the spot when the spot is East of the central meridian. The displacements are reversed when the spot is West of the central meridian.

These and other facts showed the shrewd observer that the hypothesis which is in harmony with them all, attributes the displacements to a radial movement of gases outwards from the spot's centre and parallel to the surface of the photosphere. Any explanation depending upon a vortex or rotation of any kind is negatived by the circumstance that no displacements are observed when the slit bisects a spot in a direction at right angles to a line joining the centre of the spot and the centre of the Sun's disc. To obtain confirmation of this view he took advantage of the rotation of the solar image due to the action of the heliostat. Different sections through a spot were obtainable by taking photographs at intervals throughout the day. He was thus able to compare the displacements that arose from different bisections of the spot by the slit.

During the years 1909–1915 there was minimum spot activity, and few opportunities for continuing this investigation presented themselves. In the last few years he has made a further study of this motion. He set to work with improved appliances. In order to get images representing central sections of a spot he constructed a simple guiding arrangement, which is fully described in *Bulletin* No. li. of the Kodaikánal Observatory. With these arrangements he secured fine spectra of the large spot which crossed the Sun's disc 1915 March 29 to April 15 in latitude 21° N., and made further discoveries. He found that the radial-movement displacement may be very unequal at equal distances from the umbra of a spot; detached penumbræ appear to show no radial movement except when secondary nuclei are developed in them, forming independent centres of radial motion; the radial movement may be continued for a considerable distance outside the limits of the penumbræ, or it may stop short at those limits; there is usually an acceleration of velocity from the umbra to the outer limits of the

penumbra, and then a sudden fall to zero, or to a lesser speed which diminishes to zero at some distance outside the spot; the radial movement may amount to 4 km/sec at one edge of the penumbra for lines of intensity 0 and 1 in large spots; the mean radial movement for east and west edges appearing to be constant for spots of the same diameter; there is a tendency to diffusion of the lines in the direction of displacement near the outer limits of the penumbræ in some spots, indicating turbulent motion; enhanced lines of iron and the lines of chromium, nickel, and titanium in the spectrum investigated do not show any systematic differences compared with ordinary lines of iron having the same intensities.

He also looked for movements at right angles to the radial movement, and came to the conclusion that irregular movements at right angles to the radial movement may occur in the penumbræ of spots, and that if a rotation movement occurs in some spots, it is not a constant and regular feature as is the radial movement.

The radial movement was confirmed by C. E. St. John at Mount Wilson, and he further developed the discovery in a series of important papers (*Ap. J.*, 37, 38; *C.R.*, 157; *Observatory*, 36). He found that the horizontal drift of gases in the penumbral region varies for different elements and for different lines in the same element; and he makes out a strong case for the variations being merely a function of the depth of the layer responsible for each individual line. He supports his view by considerations of intensity of lines of one element, by comparison with the magnetic fields given by the separate spot lines, and by observations of the flash spectrum.

The important results obtained by Mr. Evershed not only throw much light on the dynamics of sun-spots, but, as has been seen, they provided the foundation for other discoveries of far-reaching significance.

Pressure in the Reversing Layer.

I now come to one of the most difficult investigations which engaged the attention of our medallist.

Humphreys in the *Astrophysical Journal*, 26, published measures of the displacements, due to pressure, of the principal lines of many of the elements, and similar tables were subsequently given by Duffield in *Philosophical Transactions R.S.*, A, 208. Both tables indicate a wide variation in the amount of the displacements at a given pressure both for different elements and for different lines of the same element. It seemed to Mr. Evershed to be possible to estimate pressures in the Sun on the assumption that the spectra of the mixed metallic vapours in the reversing layer are subject to the same line displacements as occur in arc spectra when individual metallic elements are subjected to pressure in air. It was observed that absolute displacements in solar spectra cannot with certainty be assigned to pressure alone, because there may be other causes of displacement, such as motion in the line of sight. The idea therefore presented itself of considering only the

relative displacements of the different lines of an element, and thus eliminating any cause which gives an equal displacement to all the lines. Kayser's values of the iron lines in the arc at normal pressure are first of all compared with the corresponding values in Rowland's preliminary table of the solar spectrum and a table of displacement differences Sun – Arc constructed for the lines which are most and least affected. Comparing this information with Duffield's results regarding most and least affected lines at given pressures, and assuming that for pressures below 1 atmosphere the displacement is proportional to pressure, a calculation shows that the pressure in the reversing layer would be only 0·13 atmosphere, corresponding to a relative displacement towards the violet of 0·0058 of an Angström unit. Many possible sources of error which would vitiate this calculation are discussed, with the final conclusion that the pressure sought is probably less than 1 atmosphere. This estimate conflicts with those made by other observers. In particular Fabry and Buisson, by interference methods, deduced a pressure of 4 to 5 atmospheres above normal pressure, but it is observed that account was apparently not taken of the elliptic and diurnal motions of the Earth, which might well involve corrections equalling or exceeding the quantities measured.

Although Mr. Evershed himself only regards the investigation as an indication of probability, it is of great interest to note that the observations of Adams at the Mount Wilson Observatory in 1909 agree with those of Evershed in showing that the excess of pressure in spots over that on the surface of the Sun can hardly be as much as 1 atmosphere.

Eclipse Observations.

Mr. Evershed observed the total solar eclipses of 1896 (Norway), 1898 (India), 1900 (Algeria), and 1905 (Spain). He was clouded out in 1896 and in 1905, but important results were obtained in 1898 and 1900, and he has given full accounts of them in *Philosophical Transactions R.S.*, Series A, vols. **197**, **201**. In 1898 he obtained important photographs of spectra, the plates being exposed at intervals shortly before, during, and shortly after totality. One of the flash spectrum was obtained by exposure at the moment when the Fraunhofer lines were seen to disappear—that romance of astronomy—"and innumerable bright lines flashed out across the strip of continuous spectrum which still remained visible." By comparing the flash spectrum with Rowland's wave-lengths of the absorption lines in the solar spectrum, he found that practically every strong line in the latter is present in the lower chromosphere as a bright line, and whilst the positions of the bright lines in general coincide with Fraunhofer lines, the relative intensities of the bright lines are widely different from those of the absorption lines. It follows that a negative of a flash spectrum is very unlike a positive of a solar spectrum.

But as regards any one element, the relative intensities

appeared to Mr. Evershed to be practically the same. He concluded that the flash spectrum may be considered to represent the upper more extensively diffused portion of a stratum of gas which by its absorption gives the Fraunhofer dark-line spectrum. He found that nearly all the known metals having atomic weights less that 60 are represented in these spectra, and that no element of atomic weight higher than 92 could be certainly identified. There are a small number of unidentified lines which are all weak. He proved that the wave-lengths of the hydrogen lines in the ultra-violet agree with those derived from Balmer's formula, and that the prominences and lower chromosphere emit a strong continuous spectrum in the ultra-violet, beginning near the hydrogen limit and extending indefinitely in the more refrangible region. The ultra-violet hydrogen lines were found to increase in intensity towards the photosphere, but to remain narrow in the flash-spectrum layer.

In 1900 the eclipse was not quite total at the station selected, because Mr. Evershed considered that the photographs he required would be best obtained if the eclipse were not quite total. All the exposures, which were made within 15 seconds of mid-eclipse, yielded good images of the flash spectrum in high solar latitudes. The spectra are fully discussed, and appear amply to confirm the results obtained from the 1898 eclipse. An exception to this statement was, however, found in regard to the conclusions that had been reached concerning the relative intensities of the lines of any one element in the flash and Fraunhofer spectra. He was led to a re-examination of the question by some criticisms made by Fowler and Baxandall. These investigators found that the relative intensities of an element in the flash and Fraunhofer spectra approximated to those found in the spark and arc spectra respectively, and they thence concluded that the flash-spectrum layer is not the seat of the Fraunhofer absorption lines. The reconsideration of the matter led Mr. Evershed to the remark that the agreement between the two spectra is so striking, that it can scarcely be maintained that there is a fundamental difference in the conditions under which they are produced. He sought to explain the abnormal intensity of the enhanced lines in the flash by assuming the presence of innumerable eruptions of hot gas and cooler but descending absorbing gases, and was not able to abandon the view that the entire depth of the flash region, and indeed of the chromosphere itself, is effective in producing the absorption lines. His final conclusion is that the flash spectrum represents the emission of both ascending and descending gases, whilst the Fraunhofer spectrum represents the absorption of the descending gases only.

In eclipse observation Mr. Evershed has shown extraordinary resource in so arranging his apparatus that he could himself control a considerable number of operations. On each occasion it was his special desire to improve upon previous photographic records of the flash spectrum.

Concluding Remarks.

I now leave the technical side of the medallist's work to make some remarks upon its general character. Up to the present I have had a perfunctory knowledge of his achievements. Coming fresh to the subject, from the outside, and not being, like most of my hearers, in intimate touch with it, I have been chiefly impressed by the scientific spirit which pervades the work. That spirit, usually allied, as in the present case, with imagination, resource, and determination, and accompanied by technical skill of high order, is the greatest asset that a worker in science can possess, and carries him far indeed.

Some ten years ago I attended an international congress in Paris, and shortly after its inaugural meeting occurred the death of M. Loewy, the Director of the Observatory of Paris. I was one of the representatives of British Science at the funeral, and I remember hearing from one of the French astronomers present that, a day or two before his death, M. Loewy had remarked that a man of science should work as if each day was the last, and also as if life were everlasting. I think that our medallist's attitude towards scientific research is in striking accord with these noble words. We see him utilising every available hour for the collecting of material which has to wait many years before it is ripe for discussion. He is in no hurry; he allows the observations to accumulate, *e.g.* the prominence registrations, until in volume and variety they are of such a character that they can be studied with advantage.

Again, I note the delicate precision of the experiments, and the careful and unprejudiced thought with which the results are handled. He simply seeks for the Truth, without anxiety either to run a tilt at or to confirm the work of others. He has no prepossessions.

Much may be learnt from the life-history of such a man. It is not a new thought with me that a student of science should invariably supplement his reading of treatises and his laboratory education by making himself acquainted with the life and work of particular pioneers in his subject. He will thus obtain an insight into the scientific spirit which cannot be secured from the dry statements of text-books. He will learn the way in which a resolute searcher after truth applies himself, and the way in which difficulties should be encountered. He will gather to himself some of the great man's inspiration and enthusiasm, and afterwards apply himself to study and research with a more elevated mind, and from a higher point of view. He will have taken to heart that the successful worker does not, when in trouble, look helplessly around for assistance, but resolutely determines to help himself. I call to mind books written many years ago by Samuel Smiles — *Self-help*, *The Lives of the Engineers*, etc. — as good examples of the way in which the scientific spirit may be fostered. Most certainly great examples are to be found in the lives of

astronomers, for the science of the stars has a purity which is not excelled by that of any other, in spite of the fact that it calls to its aid applied mathematics and many branches of physics and chemistry. The desire to unravel the secrets of nature, and to unveil the many mysteries of the construction, constitution, and movement of the heavenly bodies, is its guiding star.

I would add that astronomy is the most highly organised of the sciences. This appears to be due in large measure to the conditions under which astronomical research of necessity is carried out. A recent instance is the Union for Co-operation in Solar Research, which after a few years of existence has added stellar physics to its domain. A result of this organisation is that it is possible to write a connected history of modern astronomy in a sense which is not possible, so far as I am aware, in any other branch of science. Much is done to this end by the splendid annual reports drawn up by our indefatigable secretaries and their coadjutors.

Greatly as I deplore my inadequate equipment for the task of laying before you some account of the work which you are honouring to-day, I leave the subject with regret. It has been an intense pleasure to imagine myself gaining a superficial knowledge of several phases of the work; to stand by Mr. Evershed's side in his observatory and catch something of his enthusiasm; to watch him deal with difficulty after difficulty like one who will not be denied; to see him surrounded by competent assistants, his powerful derivatives created by his inspiring genius. There is much in our medallist's career which is a reminder of the scientific life of Sir William Huggins. They come from the same English neighbourhood, and began as amateurs of the best kind. They both possess the same kind of scientific aptitude.

Finally, I have in thought taken my stand beside Mr. Evershed in the Valley of Cashmere, whither he went in 1913 in order to report upon the suitability of the Valley or its vicinity for the site of an observatory. There, amidst the wonderful verdure and gay flowers with which many years ago I was familiar, I hear him discuss the "seeing" and "definition" and "climate" and other points to be considered in selecting a site. It is satisfactory to know that his report is entirely favourable, and it is ardently to be hoped that the Government of India will act, as opportunity may occur, and either transfer an existing observatory to the Happy Valley or install a new one there.

In conclusion, I think that it may be fairly said that the researches under review have brought broad generalisations concerning solar meteorology appreciably nearer.

I am sure that every Fellow of the Society will consider that the medal this year could not have been more worthily bestowed, and that Mr. Evershed is a Laureate of whom we may be proud.

The Hannah Jackson (*née* Gwilt) Gift has been awarded by the Council to the Rev. T. E. R. Phillips for his Observations of Planets, Double Stars, and Variable Stars.

We see in Mr. Phillips a distinguished amateur, who, besides being a well-known and hard-working Fellow of this Society, has been for many years one of the mainstays of the British Astronomical Association. His planetary work is for the most part connected with Jupiter, and for the last fifteen years he has in the British Astronomical Association directed "The Section for the Observation of Jupiter." In the Presidential Address which he delivered in 1915 he took the great planet as his theme, and, in addition to a valuable historical summary, he gave an account of his own additions to our knowledge. He discussed at length the relation between the South Tropical Disturbance and the Great Red Spot, and the physical nature of each. He was able to draw the important inference that in all probability the Disturbance is something which has momentum, and exerts friction to the extent of displacing the Red Spot round which it flows, and he considered that the evidence pointed, in agreement with suggestions made by other investigators, to the Red Spot being a vortex of great strength, and probably deep seated below the planet's visible surface. He then in a masterly fashion considered the question of the planet's rotation. Collecting the published materials and weighing the individual results, he derived probable mean values for the various currents in different years. The whole address is most suggestive, and will be of incalculable help to future observers and students of Jovian meteorology.

I now come to what may, I think, be regarded as his most important recent work—that on the Light Curves of Long-period Variables. Standing on the shoulders of Professor Turner, he has made an excellent contribution to the discussion. The light curves differ considerably in shape, and Turner was the first to represent a curve by a Fourier Series, consisting of an absolute term denoting the mean brightness, followed by other terms denoting the first, second, third, etc., harmonics.

Taking the first harmonic to be

$$\phi \cos (\theta - \tau),$$

θ is the angle reckoned from an arbitrary starting point, and τ is the phase of the first harmonic.

Mr. Phillips referred the phases to the maximum of the first harmonic as starting point, so that the first harmonic is

$$\phi \cos (\theta - 180^\circ).$$

He then plotted the harmonics on squared paper, taking as abscissæ and ordinates the phases ϕ_2, ϕ_3 of the second and third harmonics respectively, and found that the dots *instead of forming one system, fell into two distinct groups.* The material consisted of 80 stars, and of these only 6 were left out of the groups owing to uncertainties or discordances. In view of the smallness of the coefficients of the second and third harmonics (particularly of the latter), this may be regarded as reasonably satisfactory. Examination of the phases in the two groups showed that ϕ_3 remains nearly

constant at about 200° in Group 1, while ϕ_2 has a wide range; whereas in Group 2, ϕ_2 and ϕ_3 advance sympathetically. The ranges also point to the separation into groups, since not only is the general mean range of Group 1 less than that of Group 2 stars, but also the largest range of Group 1 is less than the smallest range of Group 2. Moreover, the magnitude of the coefficients of the second harmonic is consistently greater for Group 2 than for Group 1. Mr. Phillips also discusses brightness and periodicity, and finds here also that the division into two groups is well supported.

It is an important fact, which confirms the theory that the light curves themselves when separated into the corresponding groups give visible confirmation of difference of type. In Group 1 the intervals from maximum to minimum and from minimum to maximum are not very unequal, and there is a marked tendency for the curve to show a pause on the rise. In Group 2 there is a sharp rise to maximum followed by a long period to minimum. It is almost possible to divide the curves into groups by mere inspection.

Much more might be said concerning the work of Mr. Phillips, but I must content myself with saying that in the opinion of Professor Turner and other variable star observers, a great discovery has been made which must have a very important influence on future work. The Society does well in recognising and honouring it.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected: —

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Major P. A. MacMahon, D.Sc., Sc.D., LL.D., F.R.S.

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H. F. Newall, Esq., M.A., D.Sc., F.R.S., Professor of Astrophysics, Cambridge.
J. W. Nicholson, Esq., M.A., D.Sc., F.R.S., Professor of Mathematics, King's College, University of London.
Rev. T. E. R. Phillips, M.A.

Errata in Professor de Sitter's third paper on "Einstein's Theory of Gravitation."

Page 4, footnote, line 10 from bottom, *for* "g_{44}" *read* "g_{44}^{-1}."

Page 15, formula (24), *for* $\frac{c}{kR^2 - c}$ *read* $\sqrt{\frac{c^2}{kR^2 - c^2}}$.

Pages 16–19, replace t and dt by ct and cdt.

Page 18, line 4 of postscriptum, *for* "dr/cdt" *read* "$rd\theta/cdt$."

Page 24, line 6, *for* "k" *read* "κ."

Erratum in "Presents announced," page 180.

The donor of the Herschel MSS. was the late Sir William James Herschel: his sister, Miss Francisca Herschel, was acting for him.